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WAYNE KERR

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Instruction/Service Manual
for

4225
AUTOMATIC LCR METER

MP MASTER
MA32049

Part No. 9H4225

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4225 AUTOMATIC LCR METER

Instruction/Service Manual

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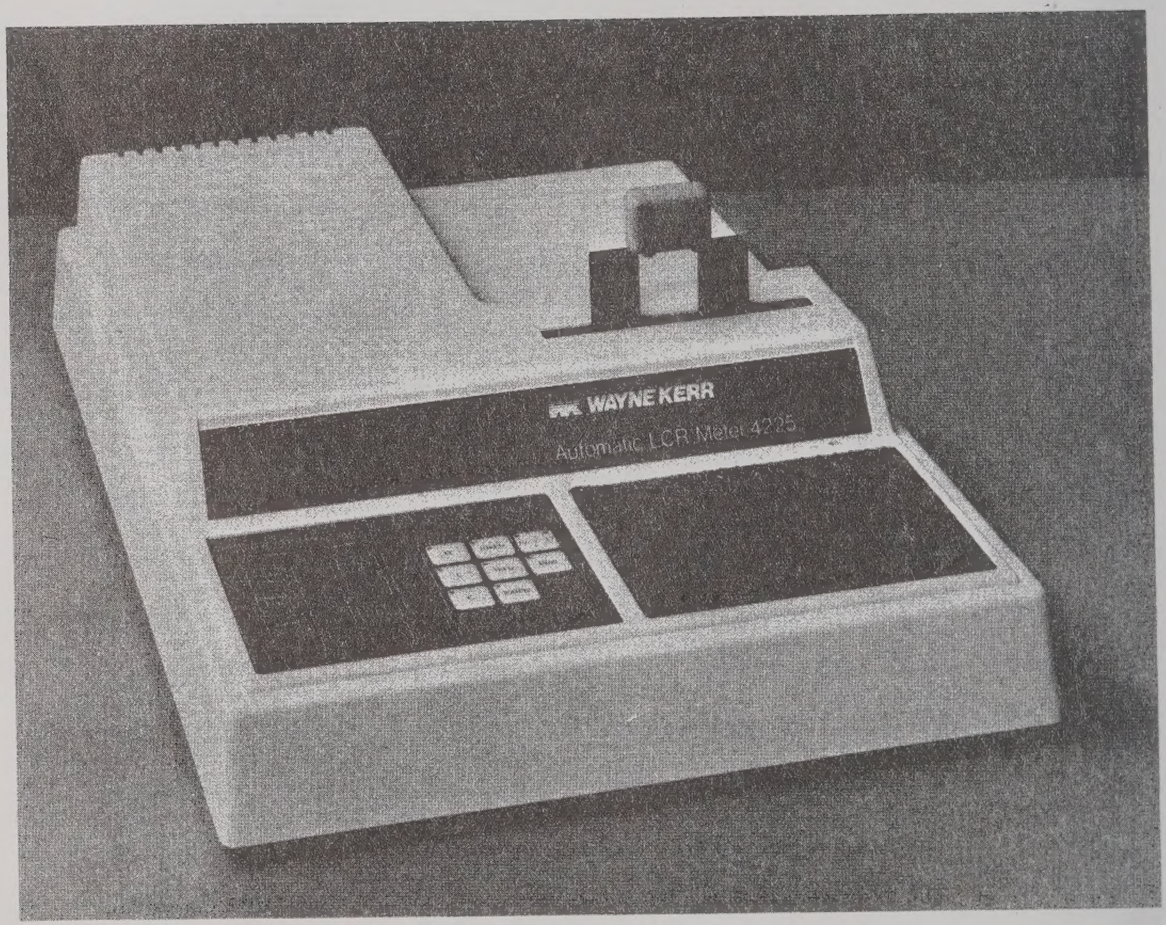

WAYNE KERR
Automatic LCR Meter 4225

INTRODUCTION

Automatic LCR Meter 4225 provides direct measurements on inductors, capacitors and resistors at any of three alternative frequencies. In addition to reading the major term (inductance L, capacitance C, and resistance R), it can be switched to measure the resistive loss term of inductors and capacitors, and any L or C term present with resistors.

The Meter can give automatic readout of the Q-factor of an inductor by computing the ratio of reactance to resistance. Similarly, for capacitors, the dissipation factor D can be read directly, the 4225 making the appropriate computation. An internal voltage is available for polarisation of capacitors when required.

Sorting components is readily achieved. Upper and lower limits of acceptance can be entered on the keypad and the display then shows PASS, HI or LO. At any time, pressing the Value key restores the normal display - without loss of limits settings - and makes the usual Q or D readings available by use of the Q/D key.

Ease of operation is the main characteristic of this compact instrument. The two spring-loaded jaws can be moved to suit the size of components under test, they accept radial or axial leads and automatically make four-terminal connections to maintain high accuracy over an extremely wide measurement range. A fifth terminal - guard - is available for neutralising the effect of unwanted shunt impedances. This facility, and the provision of a pre-set trim control, ensures reliable results even when very small values of capacitance are measured.

The 'Auto' mode of operation allows any type of component - L, C or R - to be connected and a reading to be obtained. The 4225 will automatically determine which type of component has been connected, select the most appropriate range for accurate measurement, display the numerical value (including any decimal point) and show the correct units such as mH, pF or kΩ . The user has no controls to adjust.

(Continued)

Two further features add to the flexibility of this LCR Meter. Firstly, to speed a series of checks on similar components, as in batch testing, a Hold key allows an operator to eliminate the short period of the auto-selection of L/C/R and auto-range functions. Secondly, the normal method of operation is a continuous up-date of the result every 650msec: the alternative of a 'single shot' type of measurement can be selected, the display retaining a measured value until the operator is ready for the next result.

Readout is given in the form which is the more convenient for general purposes. When the impedance lies below 1000 ohms, the values (L, C or R) are those of the equivalent series circuit : above 1000 ohms, equivalent parallel values are given. A small LED (light-emitting diode) shows which presentation is in use.

To cater for dependable measurements of transistor and diode junction capacitances, the test signal level of only 250mV rms, from a 100-ohm source, is constant on all ranges and for all types of component. The 4225 is generously protected against damage should pre-charged capacitors be connected. It will also display appropriate warning messages in the event of incorrect use.

Kelvin Lead Adaptor type 1042 simplifies connections to larger components not readily fitted to the spring-loaded jaws. A moulded box, designed to fit into the connection pillars of the instrument, has two pairs of screened leads terminated in Kelvin clips and a single lead terminated in a crocodile clip for the Guard connection. Between them, they provide all facilities for four-terminal measurements and in-situ tests.

The leads provided on the type 1042 can be removed and the required alternative leads substituted. Details of connections are described in the Lead Adaptor section of this manual (page 26).

SPECIFICATION

MEASUREMENT FUNCTIONS	L,C,R,Q,D and auto component mode.
MEASUREMENT FREQUENCIES	100Hz,1kHz,10kHz (50Hz version). 120Hz,1.02kHz,10.2kHz (60Hz version). Accuracy ±0.01%
MEASUREMENT LEVEL	250mV (±50mV) from 100Ω .
MEASUREMENT SPEED	Typically 650m sec.
DISPLAY	5 digit LED with decimal point plus individual LEDs for units/multipliers.
CONNECTION	4 terminal via integral test fixture. Includes capacitor trim control for precise measurements of small capacitors. Optional Lead Adaptor for specialised measurements.
AUTOMATIC FUNCTIONS	Auto range, with manual lock. Series/Parallel equivalent circuit. Auto component mode (R,L or C) with manual override.

ACCURACY

Beyond the ranges shown, accuracy degrades linearly

Resistance (Q<0.1)

100/120Hz	0 - 1MΩ	±0.25%±2mΩ	1MΩ - 10MΩ	±2.5%
1kHz	0 - 1MΩ	±0.25%±2mΩ	1MΩ - 10MΩ	±2.5%
10kHz	0 - 300kΩ	±.25%±50mΩ	300kΩ - 3MΩ	±2.5%

Resolution 1mΩ

Max Display 99MΩ

Capacitance (D<0.1)

100/120Hz	0 - 1600µF	±0.25%±5pF	1.6mF - 16mF	±2.5%
			16mF - 99mF	±25%
1kHz	0 - 160µF	±0.25%±0.5pF	160µF - 1600µF	±2.5%
10kHz	0 - 1.6µF	±0.25%±0.05pF	1.6µF - 16µF	±2.5%

Resolution 0.01pF

Max Display 99mF

(Continued)

(ACCURACY continued)

Inductance (Q>10)

100/120Hz	0 - 1600H	±0.25%±5μH	1.6kH - 16kH	±2.5%
1kHz	0 - 160H	±0.25%±0.5μH	160H - 1600H	±2.5%
10kHz	0 - 1.6H	±0.25%±0.5μH	1.6H - 16H	±2.5%

Resolution 10nH

Max Display 9900H

Dissipation Factor

100/120Hz	1.6nF - 1600μF	$\pm 0.0025(1+D^2)$	160pF - 1.6mF	$\pm 0.025(1+D^2)$
1kHz	160pF - 160μF	$\pm 0.0025(1+D^2)$	16pF - 1600μF	$\pm 0.025(1+D^2)$
10kHz	160pF - 8μF	$\pm 0.0025(1+D^2)$	16pF - 80μF	$\pm 0.025(1+D^2)$

Resolution 0.0001

Max Display 9900

Q Factor

100/120Hz	1.6mH - 1600H	$\pm 0.25(Q+^1/Q)\%$	160μH - 1.6kH	$\pm 2.5(Q+^1/Q)\%$
1kHz	160μH - 160H	$\pm 0.25(Q+^1/Q)\%$	1.6μH - 1600H	$\pm 2.5(Q+^1/Q)\%$
10kHz	320μH - 1.6H	$\pm 0.25(Q+^1/Q)\%$	32μH - 16H	$\pm 2.5(Q+^1/Q)\%$

Resolution 0.0001

Max Display 9900

OPERATING CONDITIONS

Temperature Range

Storage	-20°C to +60°C	(-4°F to 140°F)
Operation	0°C to +50°C	(32°F to 122°F)
For full accuracy	10°C to 30°C	(50°F to 86°F)

Power Supply 115/240V ±10%, 50/60Hz

Overall Dimensions 400 x 270 x 150mm (16 x 11 x 6in).

Weight 3.6kg (8lb)

In step with rapidly developing technology the Company is continually improving its products and therefore reserves the right at any time to alter specifications or designs without prior notice.

OPERATING INSTRUCTIONS

POWER CONNECTION

Check that the instrument is correct for the supply frequency (50 or 60Hz) and for the supply voltage (240V or 115V). To change over for different frequency or voltage, see Appendix. Fuse ratings are:

240V instruments	160mA-T
115V instruments	315mA-T

The power lead supplied with the instrument normally has the appropriate plug, to suit local a.c. supplies, moulded on. If for any reason the plug has to be replaced, the connections should be as follows:

Yellow/Green	to Earth (Ground)
Brown	to Live
Blue	to Neutral

If the plug is fused, a 3-amp fuse should be fitted.

The instrument is not suitable for battery operation.

The power on/off switch is on the back panel.

MEASUREMENT CONNECTIONS

Slide the two connection pillars to obtain a convenient spacing for the leads of the component to be measured. Axial and radial leads are equally well provided for. The jaws in each pillar are spring-loaded, providing positive four-terminal connections automatically when a component is placed in position.

Use of the optional Lead Adaptor is described on page 26.

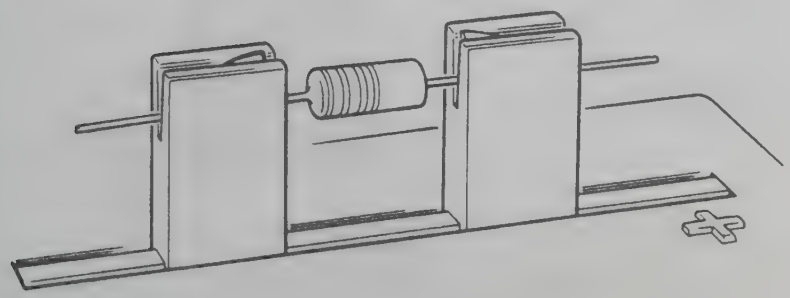


Fig. 1 Axial lead connections

INITIAL SETTINGS

At power-up, the instrument always selects a test frequency of 1kHz and operates in the Auto mode. In this condition, any type of component can be connected and its value obtained. The instrument determines automatically whether an inductor, capacitor or resistor has been connected, and automatically selects the correct range for accurate measurement.

When the instrument has already been used, possibly for other types of readout such as Q, D or Sort, these initial settings can be re-established most quickly by momentarily switching off.* As the user gains familiarity with the instrument, however, the appropriate keyboard operations will become apparent. The sequence covering all situations (as an alternative to power off-on) is:

1 Press Value

2 Press Auto

3 Press 1kHz

4 Press Measure/Continuous until its LED has flashed at least TWICE

The instrument is now in the same condition* as at power-up.

* Switching off will result in the loss of any Limits values set : the sequence of key operations will retain the limits.

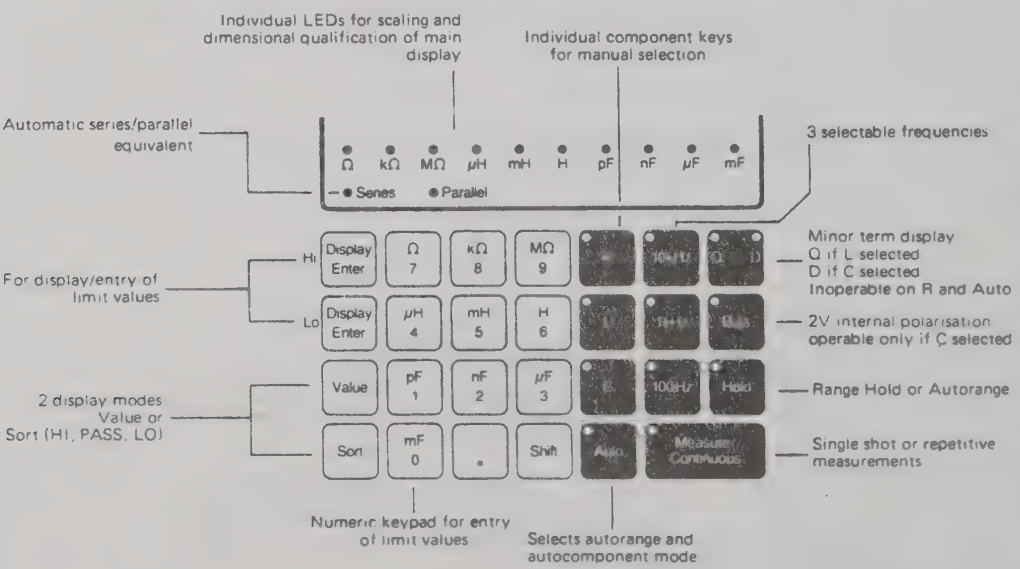


Fig. 2 Keypad

UNKNOWN COMPONENT TESTS

Assuming the instrument has the Initial Settings (see page 12), simply

1 Place the component in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED:

Ω, kΩ or MΩ for resistors
μH, mH or H for inductors
pF, nF, μF or mF for capacitors.

3 Another LED will show Series (impedances below 1000 ohms) or Parallel (above 1000 ohms). Further information on this is on page 28.

4a If the component is an inductor and the Q factor is required, see page 16.

4b If the component is a capacitor and the dissipation factor (D) is required, see page 20. Information on polarising capacitors is on page 21.

5 Remove the component and substitute the next unknown component.

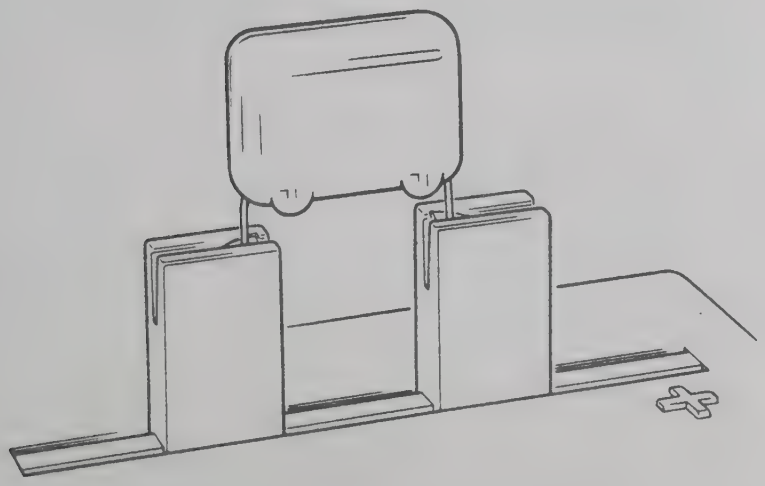


Fig. 3 Radial lead connections

TEST FREQUENCY SELECTION

The Initial Settings, as produced at switch-on, include a selection of 1kHz as the test frequency. However, users may at any time choose any one of the three test frequencies available:

50Hz operation:	100Hz	1kHz	10kHz
60Hz operation:	120Hz	1.02kHz	10.2kHz

These values are chosen to minimise interference by power-line signals.

An LED shows which frequency is in use.

Note: A change of frequency will often result in the measured impedance crossing the 1000-ohm change-over point between Series and Parallel readout. Further information on this is on page 28.

Text references to 100Hz, 1kHz and 10kHz, for 50Hz operation, apply to 60Hz operation as 120Hz, 1.02kHz and 10.2kHz, respectively.

RESISTANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 12), simply

1 Place the resistor in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED (Ω, kΩ or MΩ).

3 Remove the resistor and substitute the next one to be measured.

Note: It is not unusual for small changes to occur in the measured value of a resistor when the test frequency is changed. The effect is caused by small reactive terms which are present with all resistors. Their effect is minimal when tests are made at 100/120Hz.

The high resolution of the instrument may also show up variations in resistance due to temperature changes.

INDUCTANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 12), simply

1 Place the inductor in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED (μH, mH or H).

3 Remove the inductor and substitute the next one to be measured.

Measurement of Q Factor & Loss Resistance

With the inductor in position as described above, press L followed by the Q/D key. (The L key must have been used : Q is not available when reading inductance in the Auto mode). The display gives the Q factor. To return to inductance measurement, re-press either Q or L.

If required, the loss resistance of the inductor can be measured by selecting R, or it can be calculated from the expressions

Series: $R = \omega L/Q$

Parallel: $R = \omega LQ$

where $\omega = 2\pi \times$ frequency.

Note:

Because both the inductance and the effective loss resistance of iron-cored coils vary with the frequency and level of the test signal, and with any d.c. passed, the measured Q value will be subject to variations and these can be substantial.

Measuring small-value inductors

Small-value inductors are usually best measured at 10kHz. It must be appreciated that when an inductor is measured at a frequency much lower than that for which it is designed (e.g. an h.f. choke tested at a.f.) it will tend to behave as an inductive resistor. In these circumstances the measurement accuracy is widened by the factor (1 + 1/Q). The value of this factor can be determined by using the Q facility.

Air-cored coils are particularly susceptible to hum pick-up. For this reason, keep them well clear of mains transformers and, whenever possible, measure at 10kHz. Tests at 100Hz may be marred by noise.

Measuring iron-cored inductors

Ferrite-cored coils are usually best measured at 1kHz. Larger audio inductors, with laminated cores, are normally checked at 100Hz. When core materials can be damaged by excessive magnetisation (for example, some tape heads and microphone transformers), check before connection that the test signal level (250mV via 100Ω) is acceptable. It should also be noted that a residual 20mV d.c. is present at the measurement connections. If this is unacceptable, use the Lead Adaptor and insert a series blocking capacitor of not less than 100µF (C1 in Fig. 4).

The effective value of all iron-cored inductors can vary widely with the magnetisation and, therefore, with the level of the test signal. Ideally, they should be measured at the frequency of use, with the same a.c. and d.c. levels as apply in use. However, valuable results - especially comparative values - can usually be obtained by passing a direct current through the inductor while under test.

The essential requirements are to prevent this current entering the instrument measurement circuits, and to minimise the effect of the d.c. supply components on the measured value. To achieve this, the optional Lead Adaptor (see page 26) is required. The circuit arrangement for energising inductors is shown in Fig. 4.

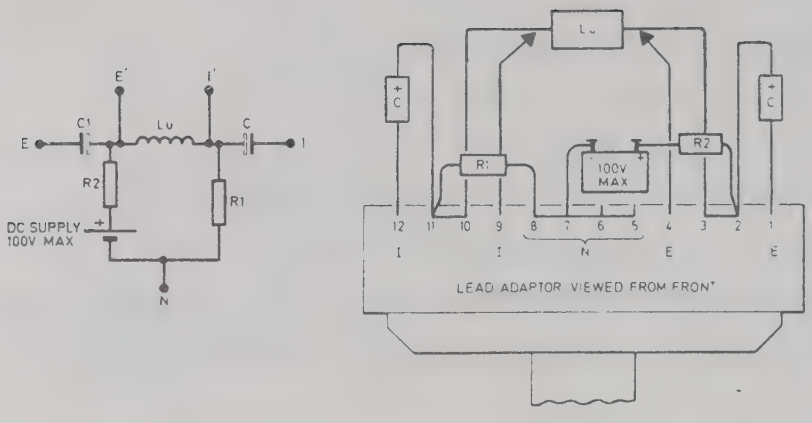


Fig. 4 Energising Inductors

Absolute maximum voltage of the supply is 100V. Care must be taken to ensure correct polarity - failure to observe this will result in permanent damage to the instrument, not covered by the Warranty, and may put the user at risk.

Lu is the inductor under test.

C1 should be ≧ 100μF and of a working voltage to suit the voltage of the d.c. supply.

The direct current through the inductor is also passed by resistors R1 and R2, which must have an adequate wattage rating. On the other hand, measurement errors will arise if the resistance values are made too low. For 1% accuracy, the minimum values for C and R1 are:

$$C = 1000\mu F \qquad R1 = 500\Omega$$

The minimum value of R2 can be found by first calculating Zu :

$$Zu = \sqrt{[Ru^2 + (2\pi fLu)^2]}$$

where Ru = resistance of unknown (Series, ohms)
f = test frequency
Lu = inductance of unknown (Series)

and, from this value of Zu, using the graph (Fig. 5) to read R2.

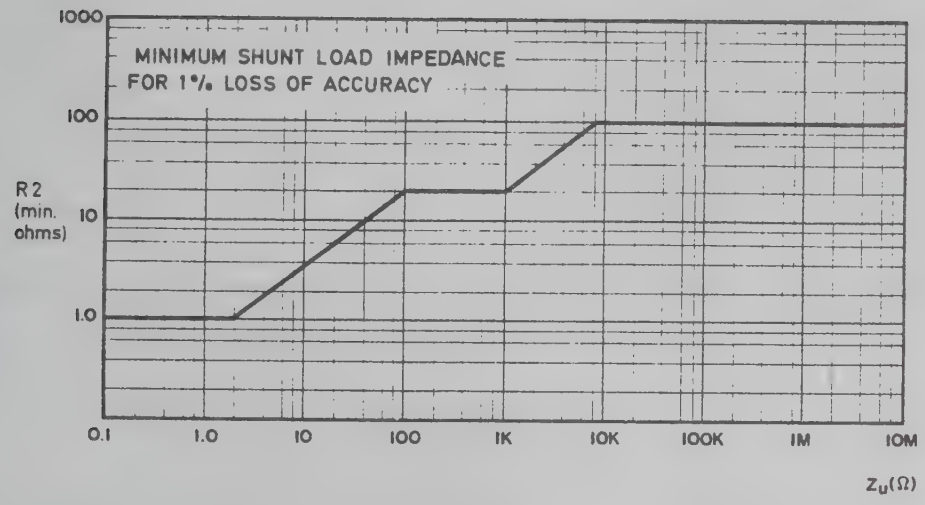


Fig. 5 Permissible Shunt Loading

The shunting effect of R1 and R2 in a given measurement can easily be assessed by substituting a short-circuit for the d.c. supply, and then noting the change in measured value when R1 and R2 are disconnected.

CAPACITANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 12), simply

1 Place the capacitor in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED (pF, nF, μF or mF).

3 Remove the capacitor and substitute the next one to be measured.

Measurement of D Factor & Loss Resistance

With the capacitor in position as described above, press C followed by the Q/D key. (The C key must have been used: D is not available when reading capacitance in the Auto mode). The display gives the dissipation factor. To return to capacitance measurement, re-press either D or C.

If required, the loss resistance of the capacitor can be measured by selecting R, or it can be calculated from the expressions

Series: $R = D/\omega C$

Parallel: $R = 1/\omega CD$

where $\omega = 2\pi$ x frequency.

Measuring small-value capacitors

The 4225 has a trim facility to provide the best accuracy when small-value capacitors are to be measured. First set the connection pillars at the separation to suit the capacitor, but do not insert the component. Press C and the required frequency key (usually 10kHz for small-value capacitors). Insert the trimming tool provided through the aperture near the legend '4225' and adjust the internal trimmer for a display of zero. Remove the trimming tool, insert the component, and read the value and units in the normal manner.

Measuring electrolytic capacitors

With a capacitor in position and with C selected (NOT Auto), pressing the Bias key will apply 2V positive bias - from an internal supply - to the right-hand connection pillar. An LED is illuminated on the Bias key while the 2V is applied : a second press of the key removes the bias.

If bias exceeding 2V is required, the optional Lead Adaptor (see page 26) is used in association with the circuit shown below:

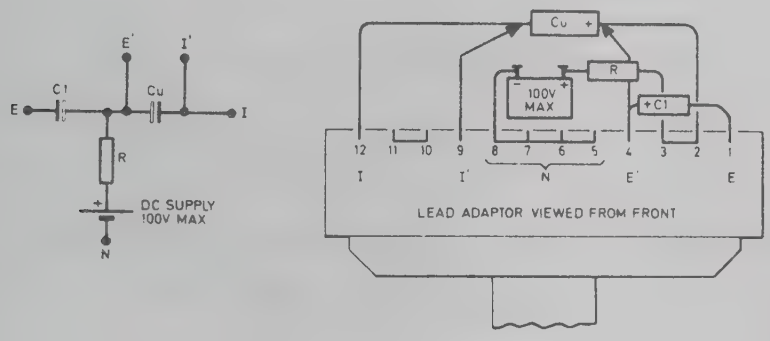


Fig. 6 Capacitor Bias exceeding 2V

Cu is the capacitor under test.

C1 should be ≥100μF and of a working voltage to suit the voltage of the d.c. supply.

Absolute maximum voltage of the supply is 100V. Care must be taken to ensure correct polarity - failure to observe this will result in permanent damage to the instrument, not covered by the Warranty, and may put the user at risk.

R should be ≥330Ω and of adequate power rating to take account of short-circuit capacitors (i.e. 100V, 330Ω , 30W).

Charged capacitor protection

Capacitors not exceeding 2μF can be charged up to 500V prior to connection to the 4225, and will cause no damage. However, larger values, up to 50mF (50,000μF) must be limited to 50V charge.

Semiconductor junction capacitance

Because of the small value of the test voltage and the availability of 2V bias, the 4225 provides quick and reliable readout of semiconductor junction capacitance.

1 Select C, Bias, and the required frequency.

2 Connect the semiconductor so that it is reverse-biased (i.e. cathode to the right-hand measurement pillar).

3 Note the value and substitute the next component to be checked, again taking care to obtain reverse bias.

CONTINUOUS/SINGLE-SHOT MEASUREMENTS

In normal use, the 4225 makes a new measurement, and updates the display, at intervals of approximately 650 milliseconds. This provides a convenient readout of changing values and - where values fluctuate very widely - indicates that the measured component is unstable or that the term requested either lies outside the coverage of the instrument or is virtually swamped by another term.

For some applications, it may be more convenient to have a one-off measurement, the result being shown on the display for as long as required. To obtain this condition, press Measure/Continuous for the duration of ONLY ONE flash of its LED. A measured value will then be stored and removal of the component under test, or substitution of another one, will not affect the readout. When another single-shot measurement is required,again press Measure/Continuous very briefly. To return to normal (Continuous) mode, press the key for at least two flashes of the LED. The mode in use is shown by this LED:

Flashing:	Continuous
Off:	Single-shot

LIMITS FACILITY

To select components whose value lies within specified limits, first measure the component in the usual manner and decide on the upper and lower limits of acceptance. Then:

1 Press Value.

2 Press Lo Display Enter. Any existing limit will be displayed.

3 Using the numeric keypad, enter the minimum acceptable value, including the decimal point. Do not exceed five figures.

4 Press Shift (marked in red).

5 Press the key for the units required (Ω ... μH ... or pF ...). (These legends are also in red).

6 Press Hi Display Enter. Any existing limit will be displayed.

7 Repeat steps 3-5 for the maximum acceptable value.

8 Press Sort.

9 Connect the component (it does not matter if a component was connected during the limits setting).

10 The display will show LO, PASS or HI.

11 Press Hold.

12 Remove the component and substitute the next one to be sorted.

Note Q and D are NOT available in the Sort mode, but Bias is (for capacitors). Also, in Sort, the frequency can be changed and single-shot operation can be used.

If required, Value can be pressed at any time for normal readout; selection is resumed - with the same limits as before - by re-pressing Sort.

If an attempt is made to enter an invalid limit (e.g. a Lo value exceeding the Hi value or a Hi limit in units of R or L when a Lo limit has already been entered in units of capacitance) the display will show LO?HI. To correct (or amend) the limit(s), press Value and then Lo or Hi as required followed by numerical value, Shift and units as before.

Using Value and Hi or Lo (but NOT entering units) allows existing limit settings to be verified.

Because the 4225 automatically sets its mode from the units information contained in the limit definition, the R, L and C keys are inoperative in the Sort mode. When a different type of component is to be sorted, switch to Value, make the new R/L/C selection and set the new limits, etc, as described above.

HOLD FACILITY

When a number of similar components are to be checked, the short time taken by the instrument for the autoranging function can be eliminated. With a component connected, and its value displayed, press Hold. The range in use (selected by the instrument) will now be held for all subsequent tests (Value or Sort). The Hold function is indicated by the LED illuminating by the Hold key. To return to autoranging, re-press Hold.

DISPLAY CHARACTERISTICS

All values displayed by the 4225 are derived by internal computation. Some of these computations may involve denominators whose value approaches zero, giving rise to large, unstable results. If a value is too large to be displayed (i.e. exceeding 99MΩ , 99mF or 9900H), the over-range indication will appear: OR

If Hold has been selected, and a component connected subsequently causes an overload, the display will be: Hold.r

The impedance may lie outside the range capability because it is an extreme value, because the frequency selected is unsuitable, or because the range Hold has been used inappropriately.

Negative Reactance

If C is selected with an inductor connected, or L with a capacitor connected, the 4225 will, within the limitations of the display, show a negative value in the terms selected. This will be the value of capacitance (or inductance) whose reactance at the test frequency is equal to that of

the component connected. It is, of course, the value to produce resonance with the component, at the test frequency. An impedance chart is shown in Fig. 8.

LEAD ADAPTOR

Connection pillars of the 4225 provide automatic 4-terminal connections to component leads. The right-hand pillar has the two contacts for E and E', the drive and measurement connections, respectively, for the source circuits. The left-hand pillar has I for the unknown current input connection to the Meter and I' as the common reference point for comparing Unknown and Standard signals.

For some applications, separate access to these four points will be required. Two instances have already been described: Energising Inductors (see Figure 4) and Capacitor Bias exceeding 2V (Figure 6). Another valuable application is the measurement of components connected into a circuit (in-situ tests). In all these instances, the use of a Neutral (N) terminal substantially eliminates the effect of components which would otherwise shunt the component under test. In Fig. 7, for example, a measurement of Zu with:

a) Z1 not less than 500Ω , and

b) Z2 not less than the value (for R2) obtained by reference to Fig. 5,

will be subject to an additional tolerance of not more than 1% from each cause. The leads from I' and E' must NOT be commoned with the I and E leads, respectively. If screened leads are used, connect the braids to Neutral.

References in this Manual to the optional Lead Adaptor relate to Kelvin Lead Adaptor type 1042. This item is described in the last two paragraphs of the Introduction (see page 8). Connections to the Kelvin clips are coded by coloured sleeves. Their relationships to Fig. 7 are as follows:

Brown	E'	1
Red	E	4
Orange	I	9
Yellow	I'	12
Guard & Screens	N	5,6,7,8

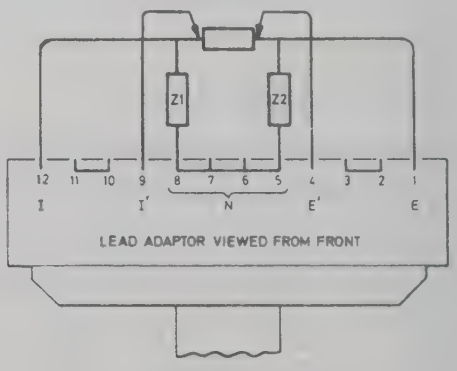
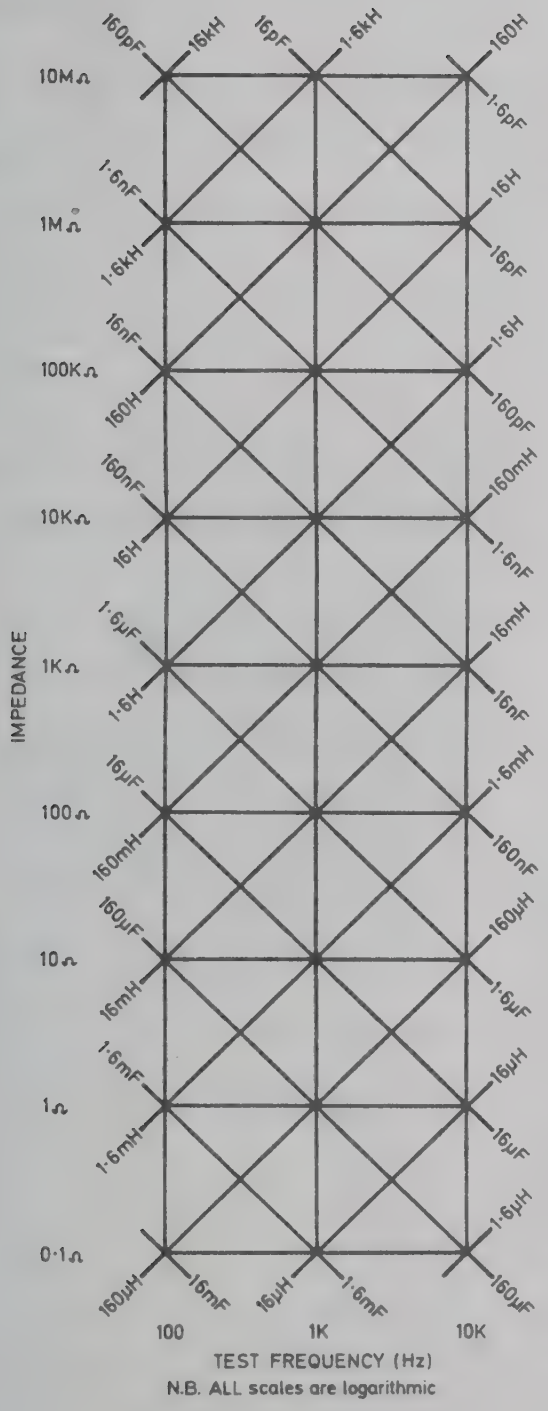


Fig. 7 Lead Adaptor for In-situ tests



Range	V_S (mV)	E_U (mV)	E_S (mV)	A_U	A_S
6	250	250 250	0·25 2·5	x2	x200
5	250	250 250	2·5 25	x2	x20
4	250	250 249	25 249	x2	x2
3	250	249 177	249 1770	x2	x0·2
2	250	177 24·9	1770 2490	x2	x0·2
1	250	24·9 2·5	2490 2500	x20	x0·2
0	250	2·5 0·25	2500 2500	x200	x0·2

$E_U > E_S$

$E_U < E_S$

E_U and E_S are based on reactive impedances and are therefore maximum values.

Fig. 8 Impedance Chart

SERIES/PARALLEL EQUIVALENT CIRCUITS

At a given frequency, a two-terminal R,C,L network can be represented in fully equivalent series or parallel circuits. The 4225 determines automatically which form is the more generally useful (series for impedances below 1000 ohms, parallel above 1000 ohms). When the alternative circuit values are required, these can be derived using the expressions:

$$Rp = Rs(1 + Q^2) \qquad Rs = \frac{Rp}{1 + Q^2}$$

$$Cp = \frac{Cs}{1 + D^2} \qquad Cs = Cp(1 + D^2)$$

$$Lp = Ls(1 + 1/Q^2) \qquad Ls = \frac{Lp}{1 + 1/Q^2}$$

It is worth noting that, for a relatively pure component, the major term will remain substantially the same in series or parallel representation. A small minor term in a series circuit is equivalent to a large term in the parallel equivalent, and vice versa. The equivalence calculated at one frequency is NOT applicable at any other frequency.

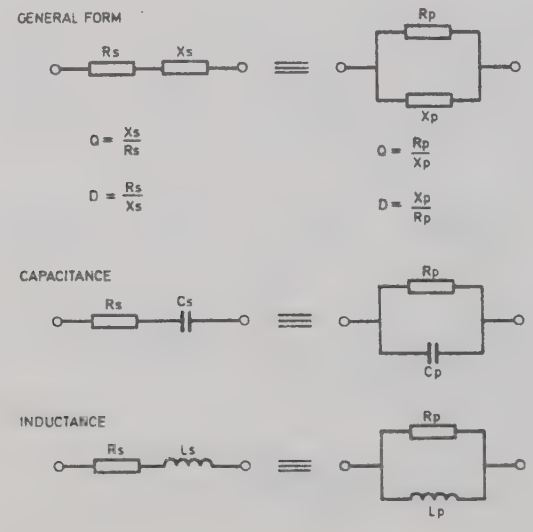


Fig. 9 Series/Parallel Equivalent Circuits

SYSTEM DESCRIPTION

MICROPROCESSOR CONTROL

All functions of the system are under the direct control of a microprocessor. Each automatic cycle of operations includes an interrogation of the keypad selections - the keys do not operate directly on the measurement circuits. The MPU then controls these circuits to obtain comparative voltages for the Unknown and Standard impedances at the selected frequency. By resolving these voltages into orthogonal components, and subsequent computation, the selected type of readout information is used to update the LED display. The computation can derive the L, C or R value of equivalent series or parallel circuits, or the ratios Q or D. Ranging is a branch from the normal measure cycle. The full sequence of operations controlled by the microprocessor is:

1 Read keypad selections

2 Select frequency

3 Select signal to be measured (Es or Eu)

4 Select measure gain

5 Select appropriate PSD reference phase

6 Control dual slope A - D converter and store results

7 Repeat steps 3 - 6

8 Calculate required parameter

9 Update display

BASIC MEASUREMENT

Refer to Fig. 10. The guard amplifier produces a feedback current through the Standard resistor, Rs, exactly matching the current through the component under test, Zu. A single measurement channel

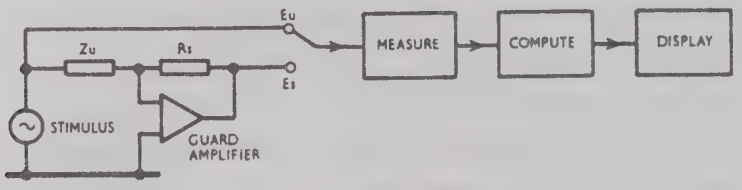


Fig. 10 Basic Measurement

is switched electronically to measure the corresponding two voltages produced, Es and Eu. Resolution of these into in-phase and quadrature components, and subsequent computations, provides the required information for the display.

OVERALL SYSTEM

A block diagram of the complete system (excluding power supplies) is shown in Fig. 11, the digital circuit diagram in Fig.21, and the analog circuit diagram in Fig 22. On Fig.11, the microprocessor is shown at the right-hand end of the 8-bit data bus. Near to it is the 16.32 MHz square-wave source IC1, from which all clock and measure frequencies are derived. A square-wave at the selected test frequency is produced by the final divider, IC112 & IC115 and then passed through the two active filter stages of IC128,129 and IC130,131. The resulting sinusoidal stimulus of 250mV rms is applied via the source resistor of 100Ω to the unknown, Zu.

The current through the unknown is converted by the virtual earth amplifier IC132 to a voltage across the standard 1kΩ resistor. The voltages across the unknown and standard, Eu and Es, are then extracted by differential amplifiers IC133-IC135. These two voltages are measured sequentially by the phase-sensitive analog/digital converter, IC143-IC146.

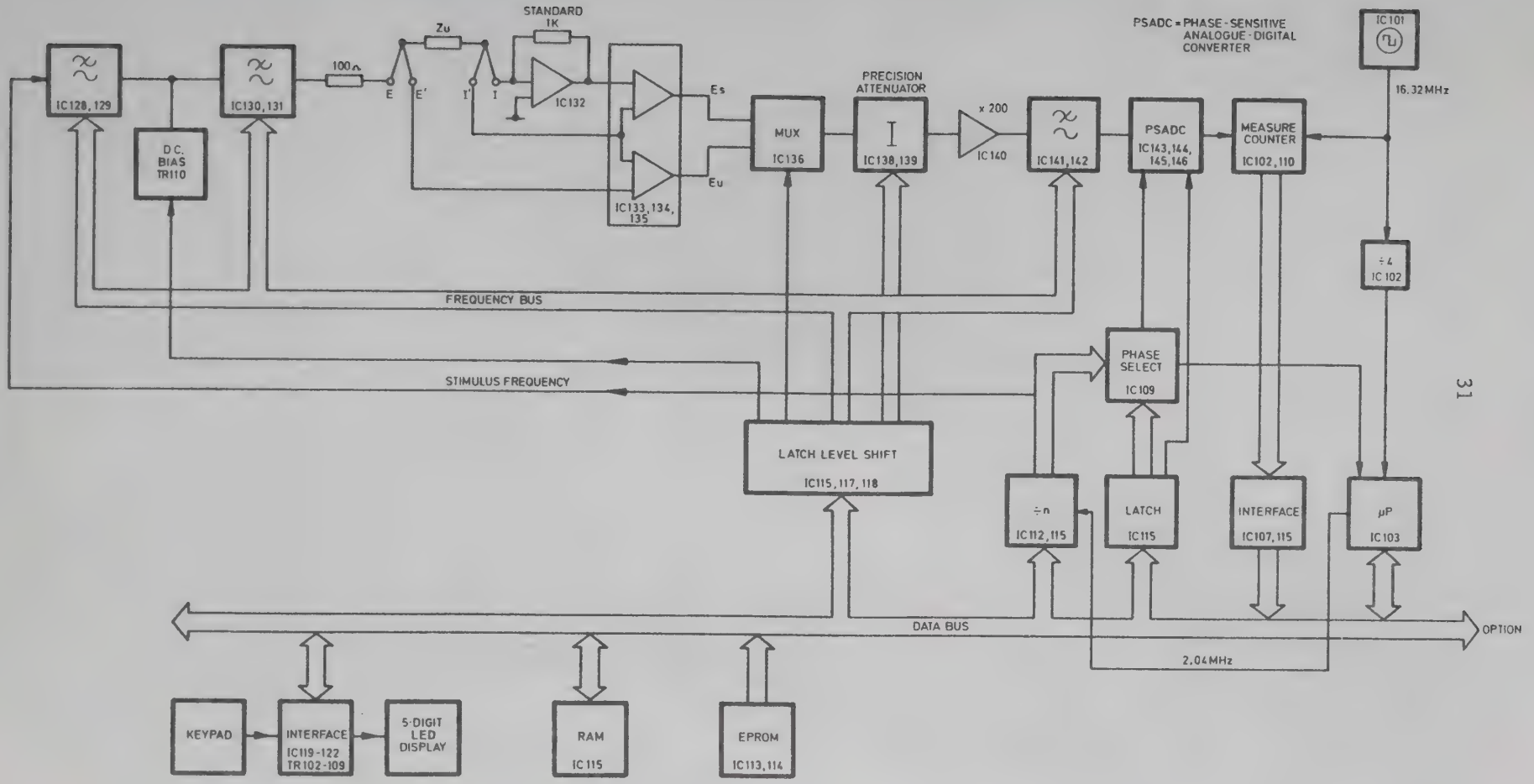


Fig. 11 Block diagram

From the values of Eu, Es and the standard resistor, the value of the unknown can be computed.

To achieve the specified impedance coverage, ranging is used. The Impedance Chart (Fig. 8) shows the coverage applicable at each of the three test frequencies.

Ranging is provided by the precision attenuator associated with IC138, 139. The phase information in Eu and Es is extracted by the phase-sensitive detector IC144. By multiplying the unknown a.c. voltage with a square-wave which is coherent with the stimulus, an output proportional to the in-phase component of the unknown voltage is obtained. A total of four such measurements, for each of which the phase of the square-wave is advanced by 90^{o}, resolves the unknown voltage into orthogonal components. Anti-phase components are added, consequently reducing noise.

The a.c. voltage from the phase-sensitive detector is integrated (on C145) for 20ms (in the 50Hz version) together with d.c. offset from IC143, which ensures that the final result is always of the same sign. The value of the voltage is obtained by timing the discharge of the capacitor with measure counter IC102,110.

Digital values produced by the measure counter are read by the microprocessor, IC103, and from these the unknown impedance is calculated. The value of the term requested is then sent to the display.

DIGITAL CIRCUITS (Fig. 21)

The 16.32 MHz clock signal from IC101 is divided by 4 in IC102 and by 2 in the microprocessor, IC103, to give 2.04MHz for the system at CLK OUT (pin 37). The microprocessor is reset at switch-on by R104, C101 (pin 36).

The operating program is stored in EPROM IC113; software for the limits facility is in IC114.* Decoding of the four highest addresses, to produce chip selects, is by IC104.

The memory map is:

0000 - 0FFF		Main software (IC113)
1000 - 1FFF		Limits software (IC114)*
4000 - 40FF		Read/Write memory (IC115)
4100 - 4103		Timer/Counter, I/O (IC115)
6000		LSB Measure Counter (IC107)
7000 - 7001		Display/Keypad encoder (IC120)

TIMER OUT on pin 6 of IC115 is programmed to produce four times the stimulus frequency :

400Hz	4000Hz	40.00kHz	(50Hz models)
480Hz	4080Hz	40.80kHz	(60Hz models)

Two sections of IC112 are interconnected to form a ring counter, the four outputs of which (pins 6,7,10,11) are at 1/4 the input frequency and in 90^{o} phase increments. One of the phases always stimulates the measure chain through C171.

IC109 is programmed via IC115 (PC2, pin 39 and PC3 , pin 1) to produce at pins 3 and 13 the four phases in sequence. Differential phase delays introduced by IC109 are removed by resynchronising with 4f in IC111 (pins 8-12).

The action of PC5 on IC115 (pin 5) going low allows PHB to change at measure frequency rate, which continues for the integrate period. This period is measured by the microprocessor which is interrupted once per cycle through its RST 7.5 input (pin 7).

At the end of the integrate period, PC5 (IC115 pin 5) will go high and PC4 (pin 2) will go low: this sets PHB high and enables the ripple-through measure counter (IC102,110) with synchronisation

* Applicable only to early models. Limits software now incorporated in IC113, and IC114 not used.

provided by IC111 (pins 2-6).

When the voltage on C145 (Fig. 22) has been reduced to zero by the current flowing from R191, the output of comparator IC146a (COMP) will go low, inhibiting the clock from IC101 (Fig. 21) to the measure counter (IC102 pin 13).

The state of the counter may now be read by the microprocessor through tristate buffer IC107 and I/O port IC115 port A (pins 21 - 28). The last part of the measurement sequence is to reset the integrator via PHA, and the measure counter via PC4 and IC111, ready for the next conversion.

Other I/O lines on IC115 control the analog filters FA,FB ; the ratio-arm gain settings GA,GB ; the a.c. voltages to be measured Eu/$\overline{Es}$; and bias on/off $\overline{BIAS}$.

On IC115, PB7 (pin 36) is an input which, at switch-on, is read by the microprocessor to determine whether a 50Hz or 60Hz version is required.

Information to be displayed is sent to IC120. The five digits of the display and the status LEDs in the keypad form a matrix of 8 x 8 (see Figs. 19 and 18).

The digits of the matrix are scanned by IC120, producing a binary count at SL0,SL1,SL2 which is decoded to 1 of 8 by IC119. Thus the anodes of each digit are driven for 1/8th of the time by TR102-TR109.

Synchronous with the selection of each set of anodes, the segments to be illuminated are selected by IC120 through IC121,122. Resistors R116 to R123 limit the current in the segments.

The 1 of 8 scan also scans the keypad matrix, key depressions being determined by reading RL0 - RL7. IC20 debounces the switch operations which are notified to the microprocessor by asserting interrupt RST6.5 (pin 8).

ANALOG CIRCUITS (Fig. 22)

The square wave at measure frequency is level shifted and cleaned by IC127a and b. There then follow two identical stages of filtering (IC128/129 and IC130/131) with control lines FA,FB selecting the appropriate one of four frequency positions:

100Hz 120Hz 1kHz/1.02kHz 10kHz/10.2kHz

Bias voltage (for polarising capacitors) is injected at IC130 pin 3 when TR110 is turned on by $\overline{\text{BIAS}}$ going low. The bias voltage is derived from the +12V supply by potential divider R144/145.

Any excess positive voltage applied to the E terminal (by, for example, connection of pre-charged capacitors) is absorbed by R196 and C146 through D110. Any excess negative voltage is caught by D111.

Open-circuit capacitance trim is provided by C122. In software 7pF is subtracted from all high impedance measurements : C122 is set to a value which together with all other strays produces an effective 7pF across the E' and I' terminals.

E and I are the terminals carrying the drive signal to the unknown: E' and I' provide sense connections to complete the four-terminal arrangement.

Virtual earth amplifier IC132, via Standard resistor R159, feeds a current to the I terminal exactly cancelling the current at this terminal from the Unknown component.

Differential amplifiers IC134 and IC135 have (pin 2) a common reference derived from the I' terminal. The non-inverting input to IC134, from the virtual earth amplifier, is a measure of the Standard voltage, Es. Input to IC135 is a measure of the Unknown voltage, Eu.

Es and Eu in sequence are passed to the measuring chain by Eu/$\overline{\text{Es}}$ controlling the multiplexer IC136.

IC137 is a buffer amplifier of unity gain.

R170,171, C131,132 perform some band-pass filtering.

Ratio arm gain selection is by IC138 and 139. Capacitor C134 provides phase adjustment at 10kHz and at gain x200. IC140 provides gain.

IC141,142 is a programmable filter to remove distortion. The short-term stability of D118 is used to provide a reference voltage for the analog to digital conversion. IC146b holds off the measure counter until ramp-down.

AUTORANGING

If a measurement is made on the wrong range, an overload of the A-D converter may occur. Under these conditions, the measure counter either will not start or it will overflow. The microprocessor will detect these conditions and select range 3 if range Hold is not selected. Whenever an overload occurs, the current measurement is aborted and a new one started. From the measurement on range 3, the best range is selected.

INTERRUPTS

Whenever a key is depressed, the microprocessor is interrupted and the current measurement is aborted. After implementing the key function, a new measurement is made (except for Limits keys).

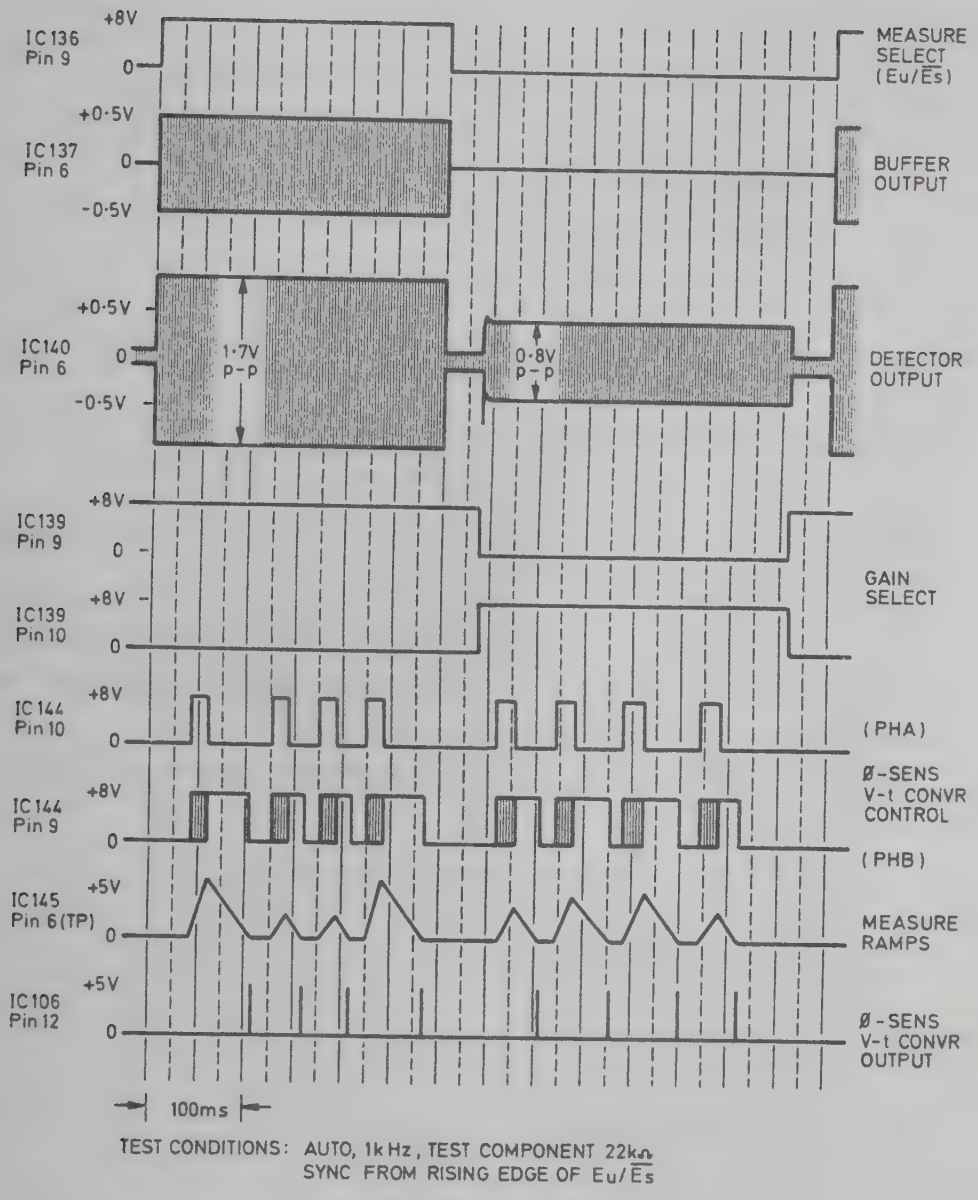


Fig. 12 Timing Waveforms

MAINTENANCE

TEST EQUIPMENT REQUIRED

1 Variac

2 AC/DC Voltmeter 0-20V dc, 0-1Vrms ac
Accuracy 0.1% at fsd
Resolution 0.1mV

3 Frequency counter to measure 1kHz to accuracy of 10 ppm

4 Oscilloscope or distortion meter

5 Capacitors:

1.5nF	±1%	Purity standard. tanδ <0.0001 at 10kHz
15.0nF	±1%	C values known to 0.01% at all three frequencies (100/120Hz,1kHz,10kHz). tan δ values known to ±0.02% at 10kHz.
1.50nF	±1%	
150pF	±1%	

6 Resistors:

10.5kΩ	±1%	Bulk film resistor known to ±0.01%
950.0Ω	±1%	Low inductance (<0.1μH) bulk film resistors, values known to ±0.01%
95.0Ω	±1%	
9.50Ω	±1%	
0.95Ω	±1%	

7 Screening bars (see Fig. 13)

8 Power Supply extension lead (see Fig. 14)

9 Keypad extension lead (see Fig. 15)

10 Trimming tool

11 Trimming tool, double-ended, to fit 4mm and 6mm cores, modified to suit Performance Check number 5.

DISMANTLING

1 Disconnect the instrument from the a.c. supply.

2 Carefully invert the unit, allowing the connection pillars to rest on a soft pad, remove 9 screws from the base-plate and lift it away. Replace 1 screw to hold the earthing tag (near the mains transformer) in position.

3 Raise the main pcb slightly by its longer side and remove two screws to release the measurement connector fixture.

4 From the main pcb, remove the keypad interconnection cable and the power supply connector.

5 Fit the base-plate, the T-shaped and plain screening bars in position (see Figures 13 and 16). Connect plain bar to ground.

6 Use the extension leads (test items 8 and 9) to reconnect the power supply circuit and keypad to the pcb. Also check that the LED Display board is properly connected to the main pcb.

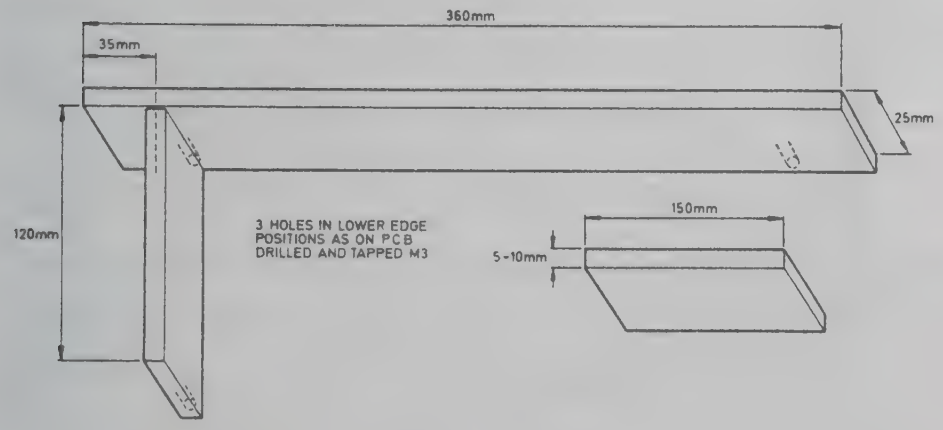


Fig. 13 (Above) Screening bars

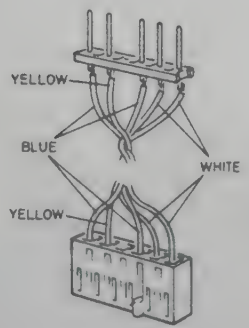


Fig. 14 (Right) Power Supply Extension Lead

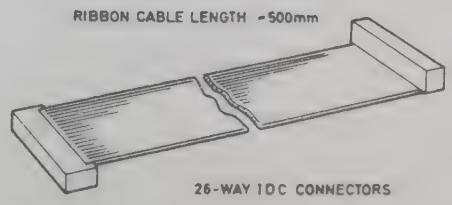


Fig. 15 Keypad Extension Lead

POWER SUPPLY CHECKS

1 Remove the power supply isolation links from SK108 (see Fig. 16).

2 From a convenient ground point on the pcb, connect resistors to SK108 as follows:

pin 2	3.1Ω	8W
pin 3	120Ω	2W
pin 4	120Ω	2W

3 Set the Variac as follows:

115-volt instruments:	103 V
240-volt instruments:	216 V

Connect the Variac to the 4225 and switch on.

4 With the voltmeter on its 0-20V d.c. range, voltages measured at SK108 should lie within these limits:

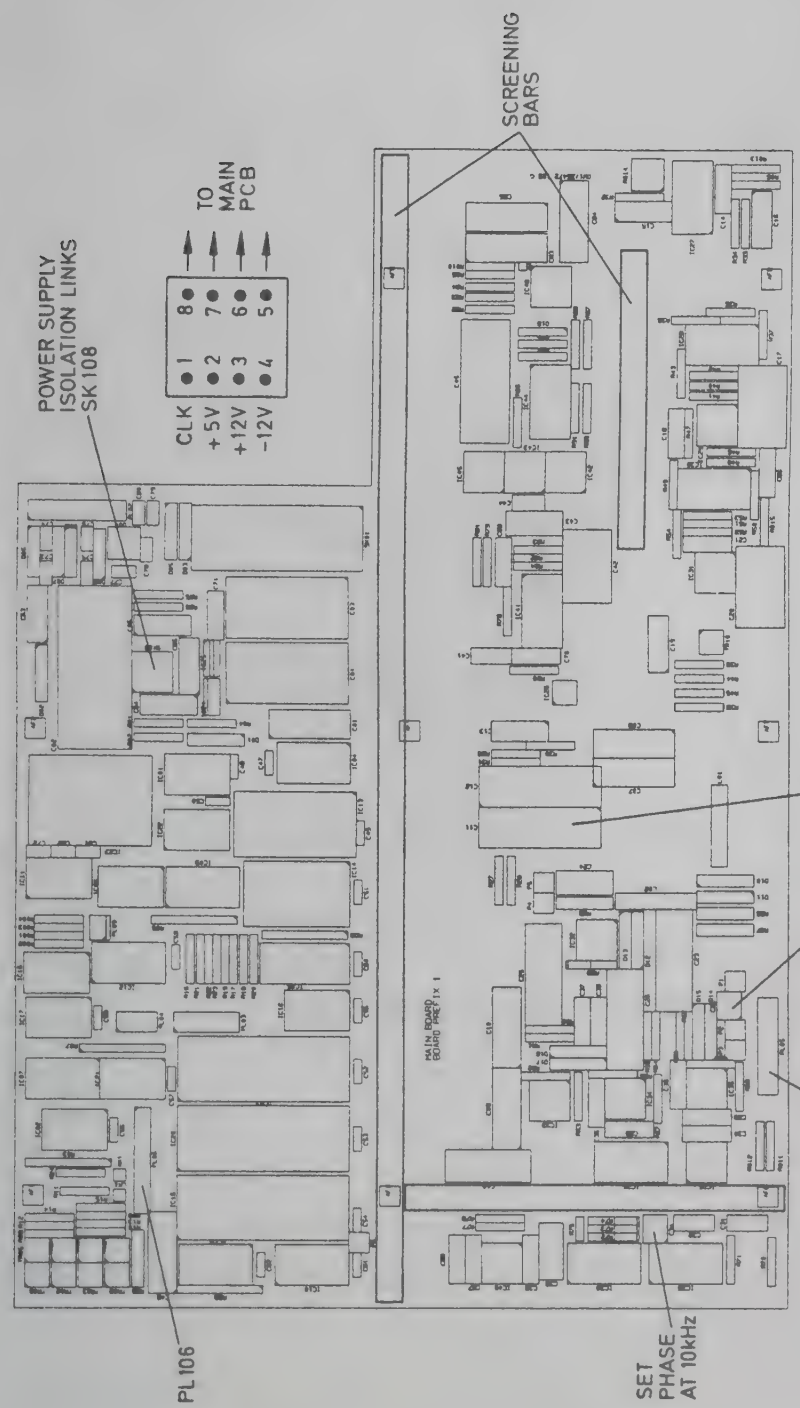
pin 2 :	+4.75	to	+5.25V
pin 3 :	+11.40	to	+12.60V
pin 4 :	-11.20	to	-12.90V

5 Switch off the a.c. supply, remove the three resistors from SK108 and re-fit the isolation links.

6 Switch on the supply. Change the voltmeter to its 0-1V a.c. range. At SK108, check that voltages do not exceed the values given:

pin 2 :	5.0mV rms max.
pin 3 :	0.5mV " "
pin 4 :	0.5mV " "

7 Change the voltmeter to its 0-20V d.c. range and check that the voltage across C11 (annotated on Fig. 16) lies between 7.8V and 8.6V.



NOTE: COMPONENT REFERENCE NUMBERS ON PCB OMIT PREFIX '1'.
LEGEND INCLUDES SOME REFERENCES NOT APPLICABLE TO 4225.

Fig. 16 PCB Layout

MEASURE FREQUENCY

1 Check that the instrument is in the normal switch-on condition, i.e. 1kHz, Auto, pF, Parallel, with Measure/Continuous LED flashing, and all others extinguished.

2 Connect the frequency counter to PL105 (annotated in Fig. 16):

Lo to pin 3
Hi to pin 1

The reading should be:

1kHz	±0.01%	(50Hz instruments)
1.02kHz	±0.01%	(60Hz instruments)

Disconnect the counter.

SOURCE SINE WAVE

1 Connect the oscilloscope (or distortion meter) to PL105:

Lo to pin 3
Hi to pin 1

Distortion on the sine wave should be less than 10%. Disconnect the oscilloscope.

2 Connect the voltmeter (0-1V a.c. range) to PL105 pins 3 and 1. The reading should lie between 200 and 308mV rms.

BIAS

1 With the voltmeter remaining on pins 3 and 1 of PL105, switch it to the 0-20V d.c. range. The d.c. voltage should be less than 20mV.

2 On the 4225 keypad, select C and Bias.

3 Check that the voltmeter now reads between 1.9 and 2.4V d.c. (PL105 pin 1 positive). Disconnect the voltmeter. Switch off and disconnect the Variac.

RE-ASSEMBLING

1 Disconnect the a.c. supply, also the extension leads from the power supply circuit and the keypad.

2 Remove the screening bars and the screw holding an earthing tag to the case (near the mains transformer). Separate the base-plate from the main pcb.

3 While lowering the board into position, check that the 5-digit LED Display board locates correctly in the slots, and remains properly connected to the pcb.

4 Re-make the connections to the power supply and keypad.

5 Ensure that the earthing solder tag is in position, and re-fit the measurement connector fixture (2 screws).

6 Check that the base-plate is correctly orientated (the hole for C34 access towards the front) and re-fit all nine screws.

PERFORMANCE CHECKS

1 Connect the 4225 to the a.c. supply (240V or 115V, according to model), and observe the display at switch-on. It should briefly show 4225.X, where X is a digit.

2 After the initial display, the only LEDs illuminated should be Auto, pF, 1kHz, Parallel, with Measure/Continuous flashing.

3 Select C and 10kHz. Insert the trimming tool through the aperture near the legend '4225' and adjust the internal trimmer for a reading between -0.01 and 0.01pF.

4 Connect the 1.5nF purity standard. The display should show between 1.4800nF and 1.5200nF.

5 Select D. Adjust C34 (accessible through a hole in instrument base plate : see Fig. 16 for location) for a reading of 0.0000 or 0.0001. Use trim tool 11.

6 Select L and 100/120Hz. Display should show:

-1689 ±20 (50Hz instruments)
-1172 ±20 (60Hz instruments)

7 Select C and 10kHz. Remove purity standard. Connect 15.0nF. Wait until display settles. Select Hold and D. Display should show 5 digits, known standard value ±25.

8 Remove 15.0nF. Connect 1.5nF. Display should show 5 digits, known standard value ±25.

9 Remove 1.5nF. Connect 10k5 ohms. Select R. Display should show 5 digits, known standard value ±26.

10 Select 100/120Hz. Display should show 5 digits, known standard value ±26.

11 Remove 10k5 ohms. Connect 950 ohms. Display should show 4 digits, known standard value ±38.

12 Remove 950 ohms. Connect 10k5 ohms. Select 1kHz. Display should show 5 digits, known value ±26.

13 As Hold is released (by re-pressing), check 'Auto r' is briefly displayed. When 'Auto r' clears, display should show 5 digits, known value ±26.

14 Select Hold, 10kHz. Display should show 5 digits, known value ±26.

15 Select 100/120Hz. Display should show 5 digits, known value ±26.

16 Remove 10k5 ohms. Connect 15.0nF. Select C. Display should show 5 digits, known value ±38.

17 Select D. Display should show 5 digits, known value ±25.

18 Remove 15.0nF. Connect 150.0pF. Select 10kHz. Display should show 5 digits, known value ±25.

19 Release Hold. Remove 150.0pF. Select Hold. Connect 150.0pF. Display should show 4 digits, known value ±3.

20 Release D (by re-pressing). Display should show 4 digits, known value ±4.

21 Select 1kHz. Display should show 4 digits, known value ±4.

22 Remove 150.0pF. Connect 1.5nF. Display should show 4 digits, known value ±4.

23 Select D. Display should show 4 digits, known value ±4.

24 Release D. Select 100/120Hz. Display should show 4 digits, known value ±4.

25 Select D. Display should show 4 digits, known value ±3.

26 Remove 1.5nF. Connect 15.0nF. Display should show 4 digits, known value ±3.

27 Release D. Display should show 4 digits, known value ±3.

28 Remove 15.0nF. Slide the two connection pillars together, and connect a short circuit (copper strip or stout wire : double-sided pcb is NOT suitable, unless the two sides are connected together). Display should show "Hold r".

29 Select L, release Hold. Display should show between -4.8µH and 5.2µH.

30 Select 1kHz. Display should show between -0.30µH and 0.70µH.

31 Select 10kHz. Display should show between -0.300µH and 0.700µH.

32 Select R, Hold. Display should show between -0.015 ohm and 0.015 ohm.

33 Select 1kHz. Display should show between -0.002 ohm and 0.002 ohm.

34 Select 100/120 Hz. Display should show between -0.002 ohm and 0.002 ohm.

35 Remove short-circuit. Re-position connection pillars. Connect 950 ohms. Release Hold. Display should show 4 digits, known value ±24.

36 Select Hold, 10kHz. Display should show 4 digits, known value ±24.

37 Remove 950 ohms. Connect 95 ohms. Select 1kHz. Display should show 4 digits, known value ±24.

38 Select 100/120Hz, L. Display should show between ±397μH of the known inductance value.

39 Select R. Display should show 4 digits, known value ±24.

40 Select 10kHz. Display should show 4 digits, known value ±24.

41 Select L. Display should show between ±3.97μH of known inductance value.

42 Select C, D. Remove 95 ohms. Connect 15.0nF. Display should show 5 digits, known value ±25.

43 Select 100/120Hz, R. Remove 15.0nF. Connect 95 ohms. Release Hold. Display should show 4 digits, known value ±24.

44 Select Hold, 10kH. Display should show 4 digits, known value ±24.

45 Select 1kHz. Remove 95 ohms. Connect 9.5 ohms. Display should show 4 digits, known value ±25.

46 Select L. Display should show between ±4.4μH of known inductance value.

47 Select 100/120Hz. Display should show between ±44μH of known inductance value.

48 Select R. Display should show 4 digits, known value ±25.

49 Select 10kHz. Display should show 4 digits, known value ±26.

50 Select L. Display should show between ±0.89μH of known inductance value.

51 Select R. Release Hold. Display should show 4 digits, known value ±26.

52 Select Hold, L. Display should show between ±0.890μH of known inductance value.

53 Select 100/120Hz. Display should show between ±44.7μH of known inductance value.

54 Select R. Display should show 4 digits, known value ±25.

55 Remove 9.5 ohms Connect 0.95 ohm. Display should show 4 digits, known value ±34.

56 Select L. Display should show between ±9.1μH of known inductance value.

57 Select 10kHz. Display should show between ±0.570μH of known inductance value.

58 Select R. Display should show 4 digits, known value ±170.

59 Release Hold. Select 1kHz. Display should show 3 digits, known value ±4.

60 Select Hold, 10kHz. Display should show 4 digits, known value ±17.

61 Select L. Display should show between ±0.570μH of known inductance value.

62 Select 100/120Hz. Display should show between ±9.1μH of known inductance value.

63 Select R. Display should show 3 digits, known value ±3.

64 Select Sort. Display should show 'LO?HI'.

65 Key in the following:
Hi, 1, ., 2, 3, 4, 5, Shift, MΩ. Display should show 1.2345MΩ.

66 Select Value, 10kHz, C. Remove 0.95 ohm. Connect 15.0nF. Display should show 5 digits, known value ±38.

67 Remove 15.0nF. Repeat step 3.

68 Switch off.

COMPONENTS LIST

RESISTORS

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R101	1k	5		Carbon	Mullard CR25
R102	10k	5		Carbon	Mullard CR25
R103	2k2			SIL N/W	Hitech L109
R104	4k7	5		Carbon	Mullard CR25
R105	10k			SIL N/W	Hitech L109
R106	10M	10		Carbon	Mullard CR25
R107	2k2			SIL N/W	Hitech L109
R108	390R	5		Carbon	Mullard CR25
R109	390R	5		Carbon	Mullard CR25
R110	390R	5		Carbon	Mullard CR25
R111	390R	5		Carbon	Mullard CR25
R112	390R	5		Carbon	Mullard CR25
R113	390R	5		Carbon	Mullard CR25
R114	390R	5		Carbon	Mullard CR25
R115	390R	5		Carbon	Mullard CR25
R116	47R	5		Carbon	Mullard CR25
R117	47R	5		Carbon	Mullard CR25
R118	47R	5		Carbon	Mullard CR25
R119	47R	5		Carbon	Mullard CR25
R120	47R	5		Carbon	Mullard CR25
R121	47R	5		Carbon	Mullard CR25
R122	47R	5		Carbon	Mullard CR25
R123	47R	5		Carbon	Mullard CR25
R124	10k	5		Carbon	Mullard CR25
R125	1k3	1	100ppm	Metal Film	Allen Bradley FC55
R126	150R	1	100ppm	Metal Film	Allen Bradley FC55
R127	68R	5		Carbon	Mullard CR25
R128	68R	5		Carbon	Mullard CR25
R129	2kO	1	100ppm	Metal Film	Allen Bradley FC55
R130	1kO	1	100ppm	Metal Film	Allen Bradley FC55
R131	1k	5		Carbon	Mullard CR25
R132	Not fitted				
R133	102k	1	100ppm	Metal Film	Allen Bradley FC55
R134	7k15	1	100ppm	Metal Film	Allen Bradley FC55

Note: Mullard type CR25 replaced by type SFR25
" " CR37 " " " SFR25H
Piher " PR50 " " Mullard SFR25H

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No
R135	665k	1	100ppm	Metal Film	Allen Bradley FC55
R136	549k	1	100ppm	Metal Film	Allen Bradley FC55
R137	60k4	1	100ppm	Metal Film	Allen Bradley FC55
R138	10k	5		Carbon	Mullard CR25
R139	1k	5		Carbon	Mullard CR25
R140	665k	1	100ppm	Metal Film	Allen Bradley FC55
R141	560k	1	100ppm	Metal Film	Allen Bradley FC55
R142	66k5	1	100ppm	Metal Film	Allen Bradley FC55
R143	6k65	1	100ppm	Metal Film	Allen Bradley FC55
R144	8k2	1	100ppm	Metal Film	Allen Bradley FC55
R145	2kO	1	100ppm	Metal Film	Allen Bradley FC55
R146	102k	1	100ppm	Metal Film	Allen Bradley FC55
R147	7k15	1	100ppm	Metal Film	Allen Bradley FC55
R148	665k	1	100ppm	Metal Film	Allen Bradley FC55
R149	549k	1	100ppm	Metal Film	Allen Bradley FC55
R150	60k4	1	100ppm	Metal Film	Allen Bradley FC55
R151	665k	1	100ppm	Metal Film	Allen Bradley FC55
R152	560k	1	100ppm	Metal Film	Allen Bradley FC55
R153	66k5	1	100ppm	Metal Film	Allen Bardley FC55
R154*	6k65	1	100ppm	Metal Film	Allen Bradley FC55
R155	47R	2		Metal Oxide	Welwyn MR5
R156	47R	5		Carbon	Mullard CR25
R157	150k	1	100ppm	Metal Film	Allen Bradley FC55
R158	47R	2		Metal Oxide	Welwyn MR5
R159	1kO	0.05	25ppm	Metal Film	Allen Bradley FC55
R160	47R	5		Carbon	Mullard CR25
R161	150k	5		Carbon	Mullard CR25
R162	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R163	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R164	47R	5		Carbon	Mullard CR25
R165	150k	1	100ppm	Metal Film	Allen Bradley FC55
R166	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R167	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R168	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R169	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R170	470R	5		Carbon	Mullard CR25

* Details differ on instruments up to Serial No. 280: see Supplement

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R171	11k	1	100ppm	Metal Film	Allen Bradley FC55
R172	47k	0.05	25ppm	Metal Film	Allen Bradley FC55
R173	4k7	0.05	25ppm	Metal Film	Allen Bradley FC55
R174	470R	0.05	25ppm	Metal Film	Allen Bradley FC55
R175	52R222	0.05	10ppm	Metal Film	Vishay VS3C1
R176*	261R	1	100ppm	Metal Film	Allen Bradley FC55
R177*	48k7	1	100ppm	Metal Film	Allen Bradley FC55
R178*	7k15	1	100ppm	Metal Film	Allen Bradley FC55
R179*	5k9	1	100ppm	Metal Film	Allen Bradley FC55
R180*	330k	1	100ppm	Metal Film	Allen Bradley FC70
R181*	30k	1	100ppm	Metal Film	Allen Bradley FC55
R182*	330k	1	100ppm	Metal Film	Allen Bradley FC55
R183*	33k	1	100ppm	Metal Film	Allen Bradley FC55
R184*	3k16	1	100ppm	Metal Film	Allen Bradley FC55
R185	680R	5		Carbon	Mullard CR25
R186*	124k	1	100ppm	Metal Film	Allen Bradley FC55
R187	15k	1	100ppm	Metal Film	Allen Bradley FC55
R188	51k	1	100ppm	Metal Film	Allen Bradley FC55
R189	15k	1	100ppm	Metal Film	Allen Bradley FC55
R190	402k	1	100ppm	Metal Film	Allen Bradley FC55
R191	51k	1	100ppm	Metal Film	Allen Bradley FC55
R192	33R	5		Carbon	Mullard CR25
R193	10k	5		Carbon	Mullard CR25
R194	4k7	5		Carbon	Mullard CR25
R195	3k3	5		Carbon	Mullard CR25
R196	27R	2		Metal Oxide	Welwyn MR5
R197	47R	2		Metal Oxide	Welwyn MR5
R198	22k			SIL N/W	Hitech L109
R199	2k2			SIL N/W	Hitech L109
R1010*	100R	5		Carbon	Mullard CR25
R1011*	1kO	1	100ppm	Metal Film	Allen Bradley FC55
R1012*	470R	1	100ppm	Metal Film	Allen Bradley FC55
R1013*	10M	10		Carbon	Mullard CR25
R1014	10k	10		Cermet	Allen Bradley E2B103
R1015*	180k	1	100ppm	Metal Film	Allen Bradley FC55

* Details differ on instruments up to Serial No. 280: see Supplement

CAPACITORS

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
C101	47µ		25V	Electrolytic	Mullard 01616479
C102	4700µ		16V	Electrolytic	Mullard 03315472
C103	1000µ		25V	Electrolytic	Mullard 03216102
C104	1000µ		25V	Electrolytic	Mullard 03216102
C105	10µ		25V	Electrolytic	Mullard 01516109
C106	Not fitted				
C107	100µ		25V	Electrolytic	Mullard 01636101
C108	100µ		25V	Electrolytic	Mullard 01636101
C109	47µ		25V	Electrolytic	Mullard 01616479
C110	47µ		25V	Electrolytic	Mullard 01616479
C111	470µ		25V	Electrolytic	Mullard 03216471
C112	470µ		25V	Electrolytic	Mullard 03216471
C113	10µ		25V	Electrolytic	Mullard 01516109
C114	470µ	2½	160V	Polystyrene	LCR FSC
C115	10µ		25V	Electrolytic	Mullard 01516109
C116	10µ		25V	Electrolytic	Mullard 01516109
C117	22n	2½	160V	Polystyrene	LCR FSC
C118	220p	2½	160V	Polystyrene	LCR FSC
C119	10µ		25V	Electrolytic	Mullard 01516109
C120	22n	2½	160V	Polystyrene	LCR FSC
C121	220p	2½	160V	Polystyrene	LCR FSC
C122	2-10p		(8mm)	Var. Tetfer	Jackson Bros. 5750/VPC
C123	4µ7	5	100V	Polyester	Wima MKS-4
C124	1n	2½	160V	Polystyrene	LCR FSC
C125	4µ7	5	100V	Polyester	Wima MKS-4
C126	4µ7	5	100V	Polyester	Wima MKS-4
C127	Not fitted				
C128	22p	1p	160V	Polystyrene	Suflex HS
C129	22p	1p	160V	Polystyrene	Suflex HS
C130	22p	1p	160V	Polystyrene	Suflex HS
C131	220n	5	100V	Polyester	Wima MKS-4
C132	10n	20	250V	Polyester	Wima MKS-4
C133	1n	2½	160V	Polystyrene	LCR FSC
C134	2-10p		(8mm)	Var. Tetfer	Jackson Bros. 5750/VPC

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
C135	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C136	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C137	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C138	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C139	33p	1p	160V	Polystyrene	Suflex HS
C140*	6µ8	5	63V	Polyester	Wima MKS-4
C141*	220n	5	100V	Polyester	Wima MKS-4
C142	8n2	2½	160V	Polystyrene	LCR FSC
C143*	2n7	2½	160V	Polystyrene	LCR FSC
C144	6p8	½p	500V	Ceramic Disc	ITT CD08/NPO
C145	100n	2	125V	Polystyrene	DRB 6007
C146	100µ		25V	Electrolytic	Mullard 01636101
C147	100n		63V	Ceramic Disc	Siemens B37449
C148	100n		63V	Ceramic Disc	Siemens B37449
C149	100n		63V	Ceramic Disc	Siemens B37449
C150	100n		63V	Ceramic Disc	Siemens B37449
C151	100n		63V	Ceramic Disc	Siemens B37449
C152	100n		63V	Ceramic Disc	Siemens B37449
C153	100n		63V	Ceramic Disc	Siemens B37449
C154	100n		63V	Ceramic Disc	Siemens B37449
C155	100n		63V	Ceramic Disc	Siemens B37449
C156	100n		63V	Ceramic Disc	Siemens B37449
C157	100n		63V	Ceramic Disc	Siemens B37449
C158	100n		63V	Ceramic Disc	Siemens B37449
C159	100n		63V	Ceramic Disc	Siemens B37449
C160	100n		63V	Ceramic Disc	Siemens B37449
C161	100n		63V	Ceramic Disc	Siemens B37449
C162	100n		63V	Ceramic Disc	Siemens B37449
C163	10µ		25V	Electrolytic	Mullard 01516109
C164	10µ		25V	Electrolytic	Mullard 01516109
C165	10µ		25V	Electrolytic	Mullard 01516109
C166					
C167	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C168	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C169	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C170	47n		40V	Ceramic Disc	ITT Transcap TD16/K3

* Details differ on instruments up to Serial No. 280: see Supplement

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
C171	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C172	10n		40V	Ceramic Disc	ITT TD08K3
C173	10n		40V	Ceramic Disc	ITT TD08K3
C174	10n		40V	Ceramic Disc	ITT TD08K3
C175	10n		40V	Ceramic Disc	ITT TD08K3
C176	10n		40V	Ceramic Disc	ITT TD08K3
C177	10n		40V	Ceramic Disc	ITT TD08K3
C178	10n		40V	Ceramic Disc	ITT TD08K3
C179	10n		40V	Ceramic Disc	ITT TD08K3
C180	10n		40V	Ceramic Disc	ITT TD08K3
C181	10n		40V	Ceramic Disc	ITT TD08K3
C182	10n		40V	Ceramic Disc	ITT TD08K3
C183*	47µ		25V	Electrolytic	Mullard 01616479
C184*	47µ		25V	Electrolytic	Mullard 01616479
C185*	47µ		25V	Electrolytic	Mullard 01616479
C186*	56p	2½	160V	Polystyrene	LCR FSC
C187*	100p	10	500V	Ceramic Disc	ITT CD08/N3300
C190	1n		500V	Ceramic Disc	ITT CD08/K2

INTEGRATED CIRCUITS

Ref	Description	Supplier & Type No.
IC101	Oscillator 16.32MHz ±0.01%	ITT DIL 1100C
IC102		Texas SN 74LS 393N
IC103		Intel P8085A
IC104*		Texas SN 74LS 139N
IC105		Texas SN 74LS 373N
IC106		Texas SN 74LS 32N
IC107		Motorola MC14503BCP
IC108		
IC109		RCA,National or SGS only. CD4052BE
IC110		RCA CD4040BE
IC111		RCA CD4013BE
IC112		National CD40175BCN
IC113*	Programmed to DW4/25490	D2764-4 Programmed
IC114*		
IC115		Intel P8155

* Details differ on instruments up to Serial No. 280: see Supplement

Ref	Description	Supplier & Type No.
IC116		RCA CD4025BE
IC117		Texas SN 74LS 26N
IC118		Texas SN 74LS 26N
IC119		Texas SN 74LS 138N
IC120		Intel P8279-5
IC121		Texas SN 74LS 38
IC122		Texas SN 74LS 38
IC123	Voltage Regulator	National LM78-05-CP
IC124	Voltage Regulator	National LM78-M12-CP
IC125	Voltage Regulator	National LM337 MP
IC126		Fairchild µA 78L82 AWC
IC127*		RCA, National or SGS only. CD4053BE
IC128		RCA or SGS only. CD4052BE
IC129		Texas TL071CP
IC130		RCA or SGS only. CD4052BE
IC131		Texas TL071CP
IC132		Texas TL071CP
IC133		Signetics NE5534AN
IC134		Signetics NE5534AN
IC135		Signetics NE5534AN
IC136		RCA, National or SGS only. CD4053BE
IC137		Signetics NE5534AN
IC138		RCA, National or SGS only. CD4053BE
IC139		RCA or SGS only. CD4052BE
IC140		Signetics NE5534AN
IC141		RCA or SGS only. CD4052BE
IC142		Texas TL071CP
IC143		Texas TL070CP
IC144		RCA or SGS only. CD4052BE
IC145		Texas TL071CP
IC146		National LM393N

* Details differ on instruments up to Serial No. 280: see Supplement

DIODES

Ref	Description	Supplier & Type No.
D101		Mullard 1N4006
D102		Mullard 1N4006
D103		Mullard 1N4006
D104	Bridge Rectifier	Internat'l Rectifier 1KAB10
D105		Mullard 1N4006
D106		Internat'l Rectifier 30S1
D107		Internat'l Rectifier 30S1
D108		Internat'l Rectifier 30S1
D109		Internat'l Rectifier 30S1
D110		Mullard 1N4006
D111		Mullard 1N4006
D112		Mullard 1N4006
D113		Mullard 1N4006
D114		Mullard 1N4006
D115		Mullard 1N4006
D116		Mullard 1N4006
D117		Mullard 1N4006
D118	4.7V	Mullard BZX79-C4V7
D201	Display LED, 7 segment	Hewlett-Packard 5082-7750
D202	Display LED, 7 segment	Hewlett-Packard 5082-7750
D203	Display LED, 7 segment	Hewlett-Packard 5082-7750
D204	Display LED, 7 segment	Hewlett-Packard 5082-7750
D205	Display LED, 7 segment	Hewlett-Packard 5082-7750

TRANSISTORS

TR101	
TR102	Texas 2N3702
TR103	Texas 2N3702
TR104	Texas 2N3702
TR105	Texas 2N3702
TR106	Texas 2N3702
TR107	Texas 2N3702
TR108	Texas 2N3702
TR109	Texas 2N3702
TR110	Texas 2N3702

MISCELLANEOUS

Ref	Description	Supplier & Type No.
FS1	Fuse Holder	Belling & Lee L2006A
F1	Fuse 160mA-T (230V)	Belling & Lee L2080A
F1	Fuse 315mA-T (115V)	Belling & Lee L2080A
L101	Inductor 3µH3	Sigma SC10
L102	Inductor 3µH3	Sigma SC10
LK101	Link	B.T. Cu wire 1/0.7
PL1	CEE22 "Clip-in" Appl. Inlet	Rendar R470 30 000
PL102	Connector Elect. Wafer	Molex 3003 10-08-1061 6 way
PL103 } PL104 }	15-way Connector (Mod'fd Molex)	WKR 5-524-5493
PL105	Plug (Modified MKS)	WKR 5-524-5460
PL106	Connector Elect. Header	Spectra-Strip 800-583 2 x 13way
PL107		
PL108	Programmable Header	Aries 8-680-191T
PL109*	Wafer 3 way 6410	Molex 22-27-2030
PL306	(Part of Membrane Keypad)	
SK2	6-way Connector 7823	Molex 10-81 2063
SK5	(Part of Connection Fixture)	
SK101	40-pin DIL Expansion Connector	Greenpar DL2 40S
SK108	IC Socket DIL 8 pin	R Nugent ICN-083-S3T
SK203	(Part of 5-Digit LED Display)	
SK204	PCB Connector. Rt. angle. 5 way	Molex 4455-A. 22-15-2056
SW1	Mains Rocker Switch	Arrow Hart 2600-11E
T1	Mains Transformer	WKR 4-524-5474
-	Membrane Keypad (100Hz)	WKR 4-524-5478
-	Membrane Keypad (120Hz)	WKR 4-524-5462
-	Membrane Interconnection Cable	WKR 5-524-5487
-	Connection Fixture	WKR 5-524-5488
-	5-Digit LED Display	WKR 5-524-5477
-	Main Board (inc.PL102/3/5/6)	WKR 5-524-5473

* Details differ on instruments up to Serial No. 280: see Supplement

SUPPLEMENT to Components List

Differences applicable to 4225 Instruments up to Serial No. 280

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R176	1k2	1	100ppm	Metal Film	Allen Bradley FC55
R177	220k	1	100ppm	Metal Film	Allen Bradley FC55
R178	49k9	1	100ppm	Metal Film	Allen Bradley FC55
R179	21k5	1	100ppm	Metal Film	Allen Bradley FC55
R180	3M0	1	100ppm	Metal Film	Allen Bradley FC70
R181	147k	1	100ppm	Metal Film	Allen Bradley FC55
R182	169k	1	100ppm	Metal Film	Allen Bradley FC55
R183	26k1	1	100ppm	Metal Film	Allen Bradley FC55
R184	2k4	1	100ppm	Metal Film	Allen Bradley FC55
R186	140k	1	100ppm	Metal Film	Allen Bradley FC55
R1010	(Not used)				
R1011	(Not used)				
R1012	(Not used)				
R1013	(Not used)				
R1015	(Not used)				

C140	1µ5	5	100V	Polyester	Wima MKS-4
C141	33n	5	250V	Polyester	Wima MKS-4
C143	560p	2½	160V	Polystyrene	LCR FSC
C183	(Not used)				
C184	(Not used)				
C185	(Not used)				
C186	(Not used)				
C187	(Not used)				

IC104		Texas SN 74LS 138N
IC113	Programmed to DW4/25490	D2732A-4 Programmed
IC114	Programmed to DW4/25490	D2732A-4 Programmed
IC127		RCA CD4001BE

PL109	(Not used)

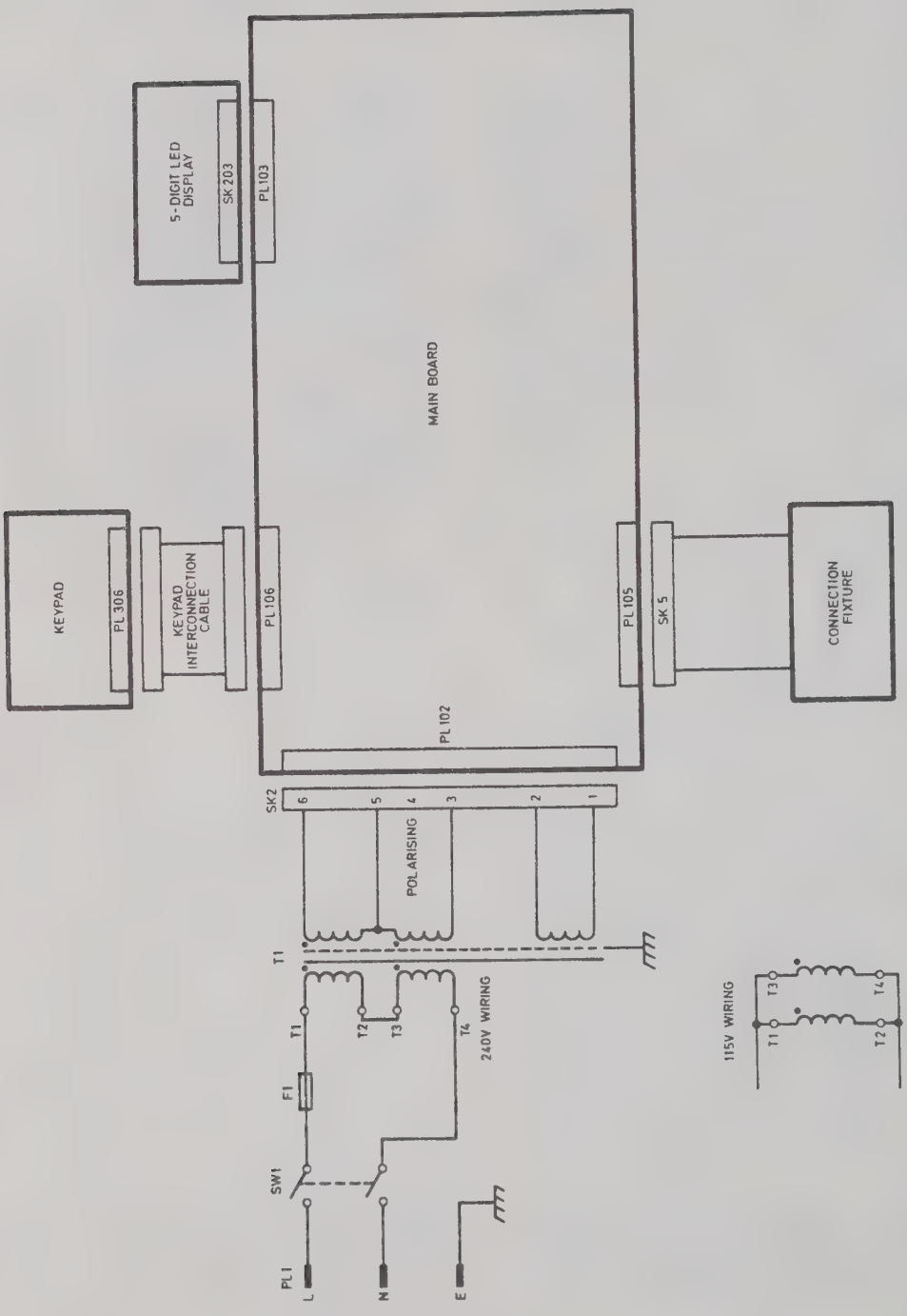
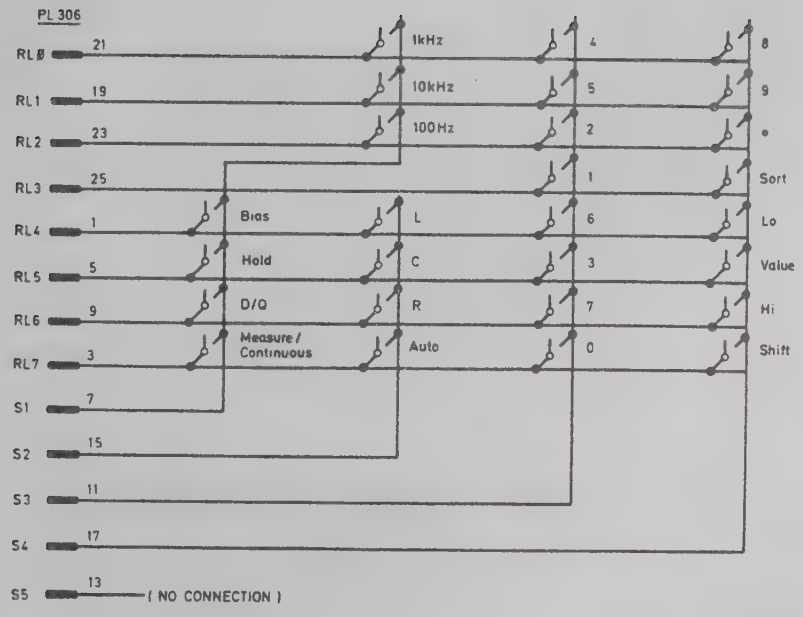


Fig. 17 Interconnection Diagram



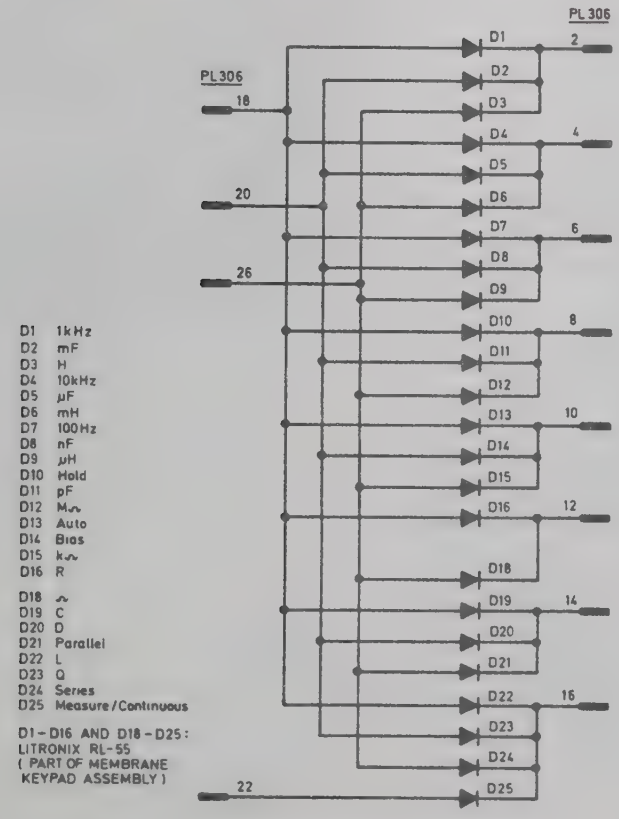


Fig. 18 Keypad Circuit Diagram

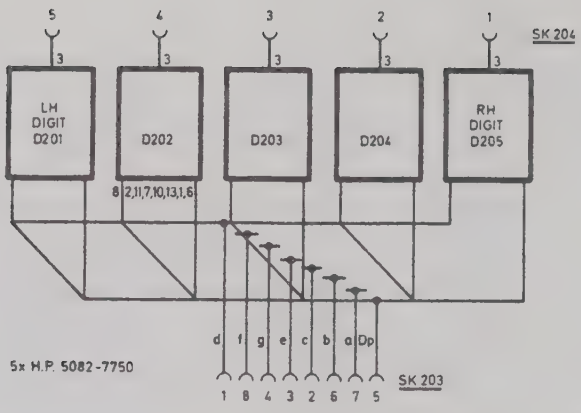


Fig. 19 5-digit LED Display Circuit Diagram

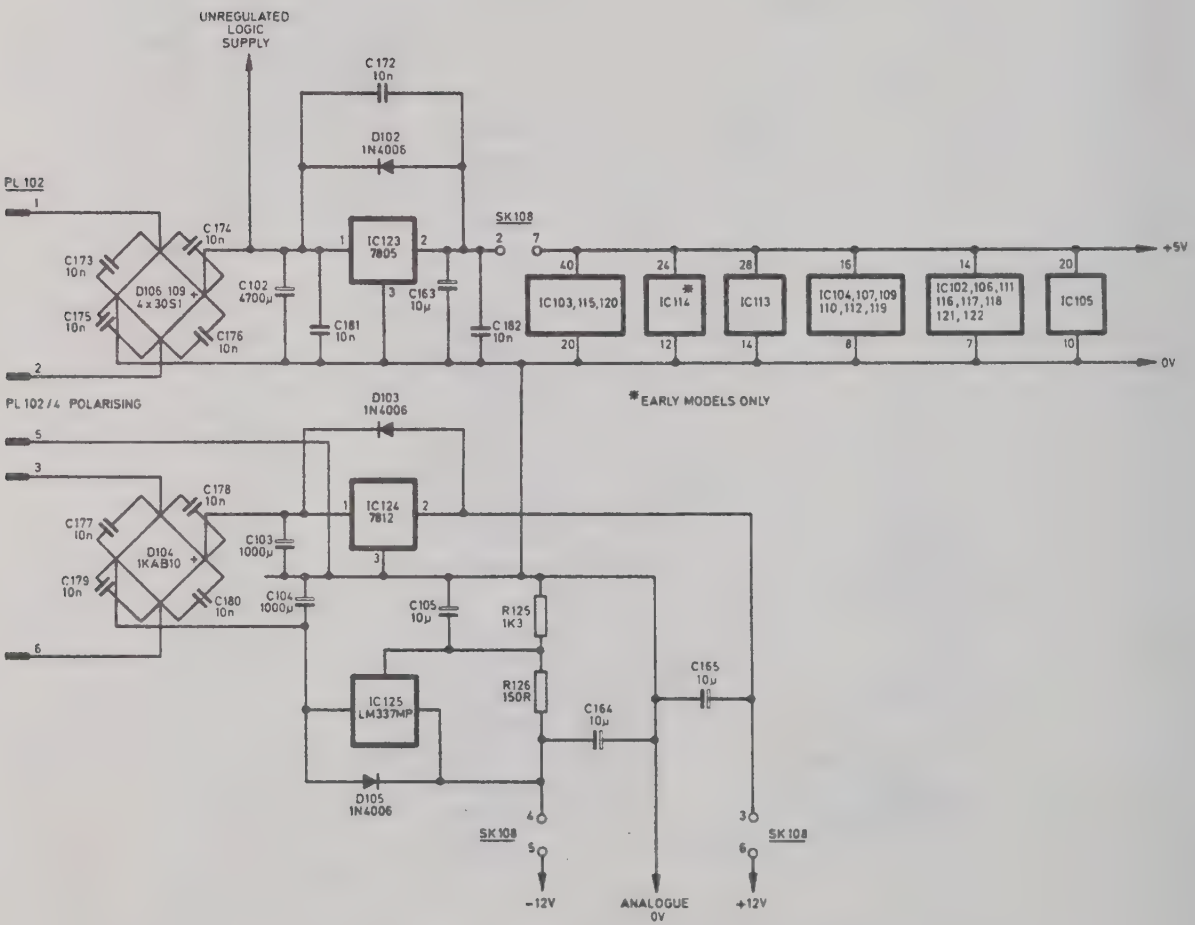
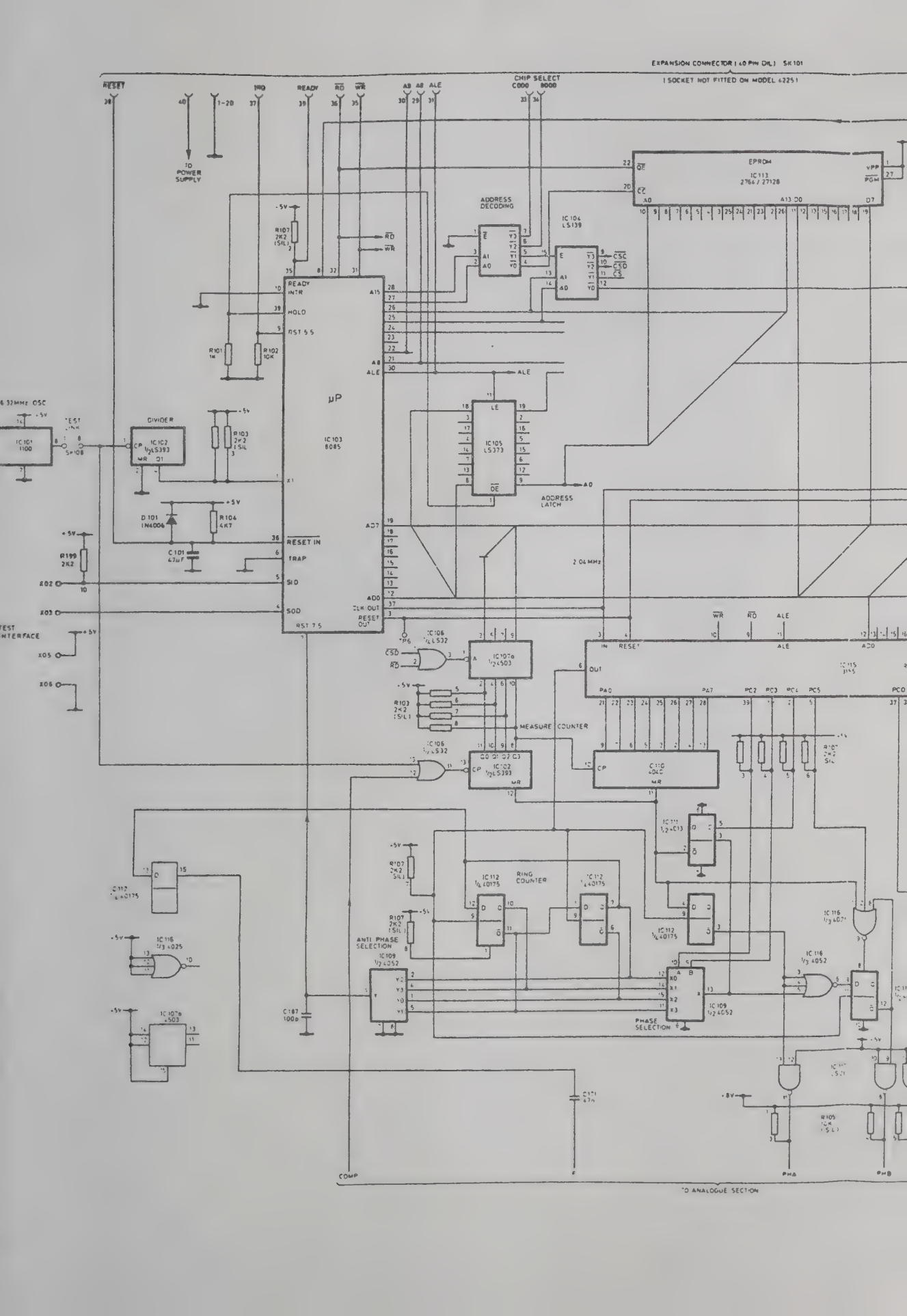


Fig. 20 Power Supply Circuit Diagram


EXPANSION CONNECTOR (40 Pin DIL) SK101
(SOCKET NOT FITTED ON MODEL 62251)
RESET
INTO
READY
RD
WR
AB
ALE
CHIP SELECT C000 8000
TO POWER SUPPLY
EPROM
IC113 2764 / 27128
ADDRESS DECODING
IC104 LS139
R107 2K2 (5IL)
R101 1K
R102 10K
READY
INTR
HOLD
RST 5.5
μP
IC103 8085
A15
A8
ALE
ADDRESS LATCH
IC105 LS373
AD7
AD0
CLK OUT
RESET OUT
RESET IN
TRAP
SID
SOD
RST 7.5
6.32MHz OSC
IC101 1100
SP108
DIVIDER
IC102 ½LS393
R103 2K2 (5IL)
D101 IN4006
R104 4K7
C101 47μF
R199 2K2
2.04 MHz
IC106 ¼LS32
IC107a ½4503
MEASURE COUNTER
IC110 4042
IC111 ½4013
IC112 ¼40175
RING COUNTER
ANTI PHASE SELECTION
IC109 ½4052
PHASE SELECTION
IC116 ⅓4052
IC116 ⅓4025
IC107b 4503
C107 100p
C171 47n
COMP
TO ANALOGUE SECTION
PHA
PHB

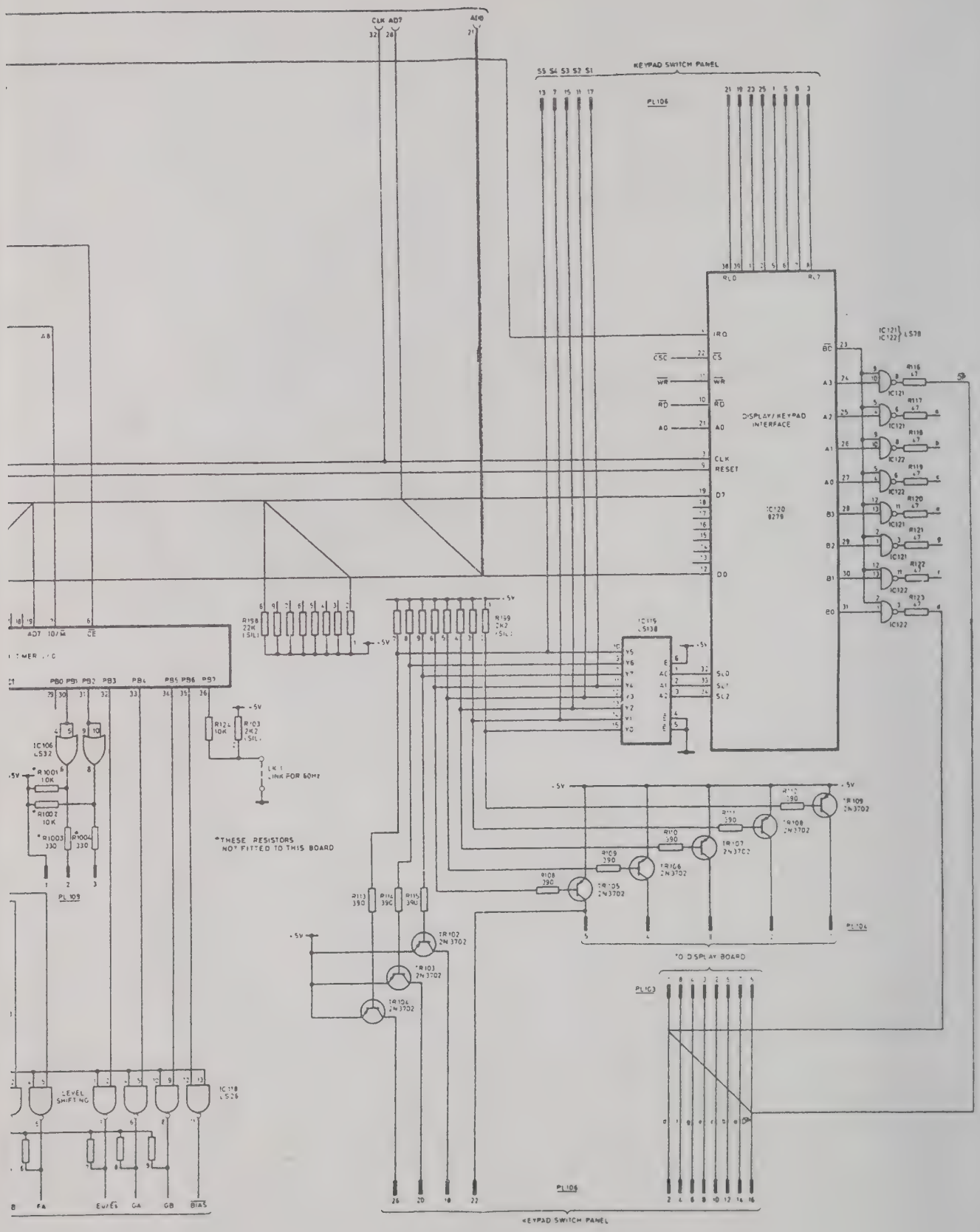
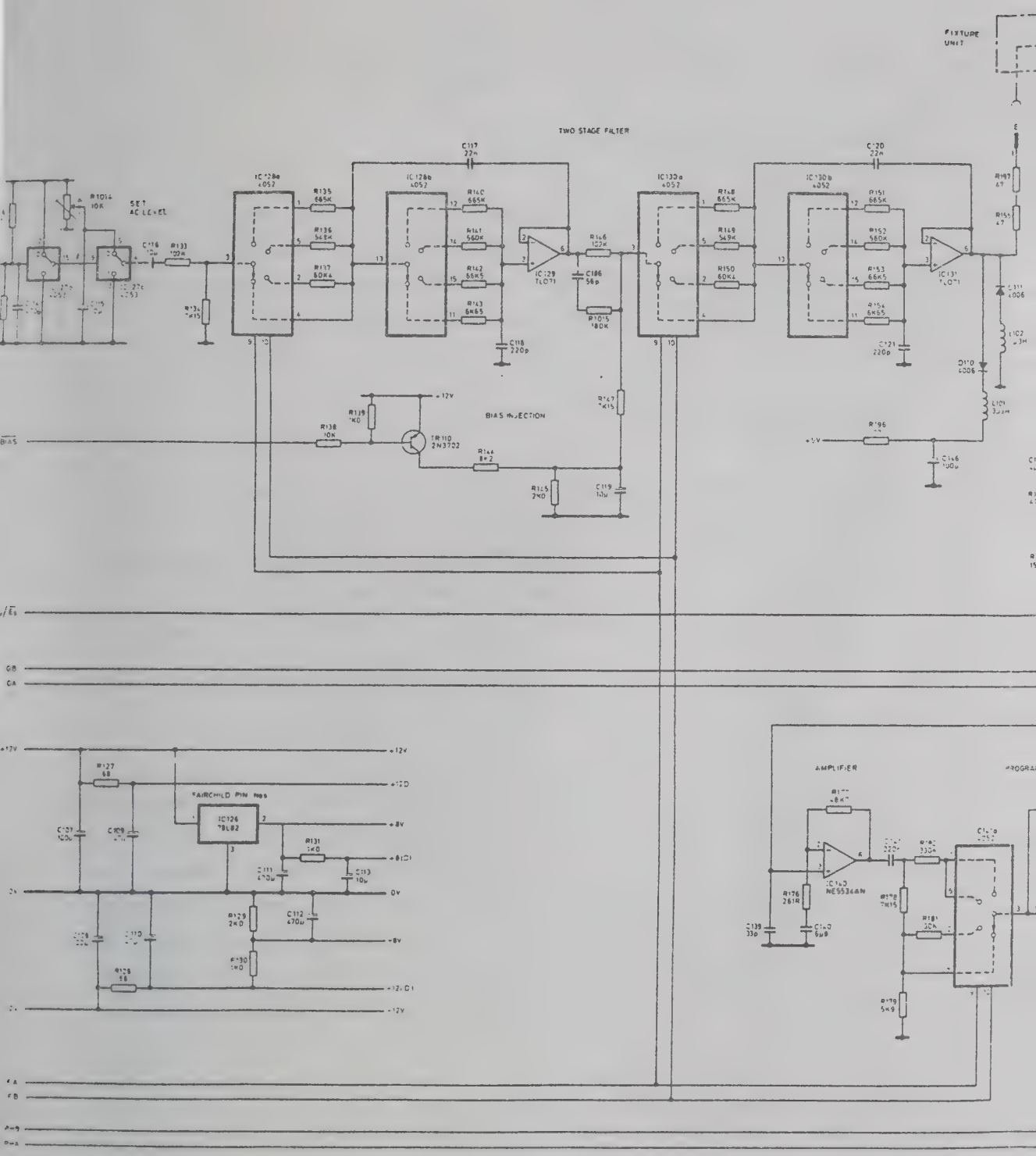


Fig. 21 Digital Circuit Diagram



	IC127	IC128	IC129	IC130	IC131	IC132	IC133	IC134	IC135	IC136	IC137	IC138	IC139	IC140	IC141	IC142	IC143	IC144	IC145	IC146
+12V					7	7										7	7		7	8
+8							7	7			7			7						
+8(D)	16	16		16											16			16		
0V										15		16	16							
-8	6 8	6 8		6 8						6 8		6 8	6 8		6 8			6 8		
-8(D)							4	4	4		4									
-12V					4	4														

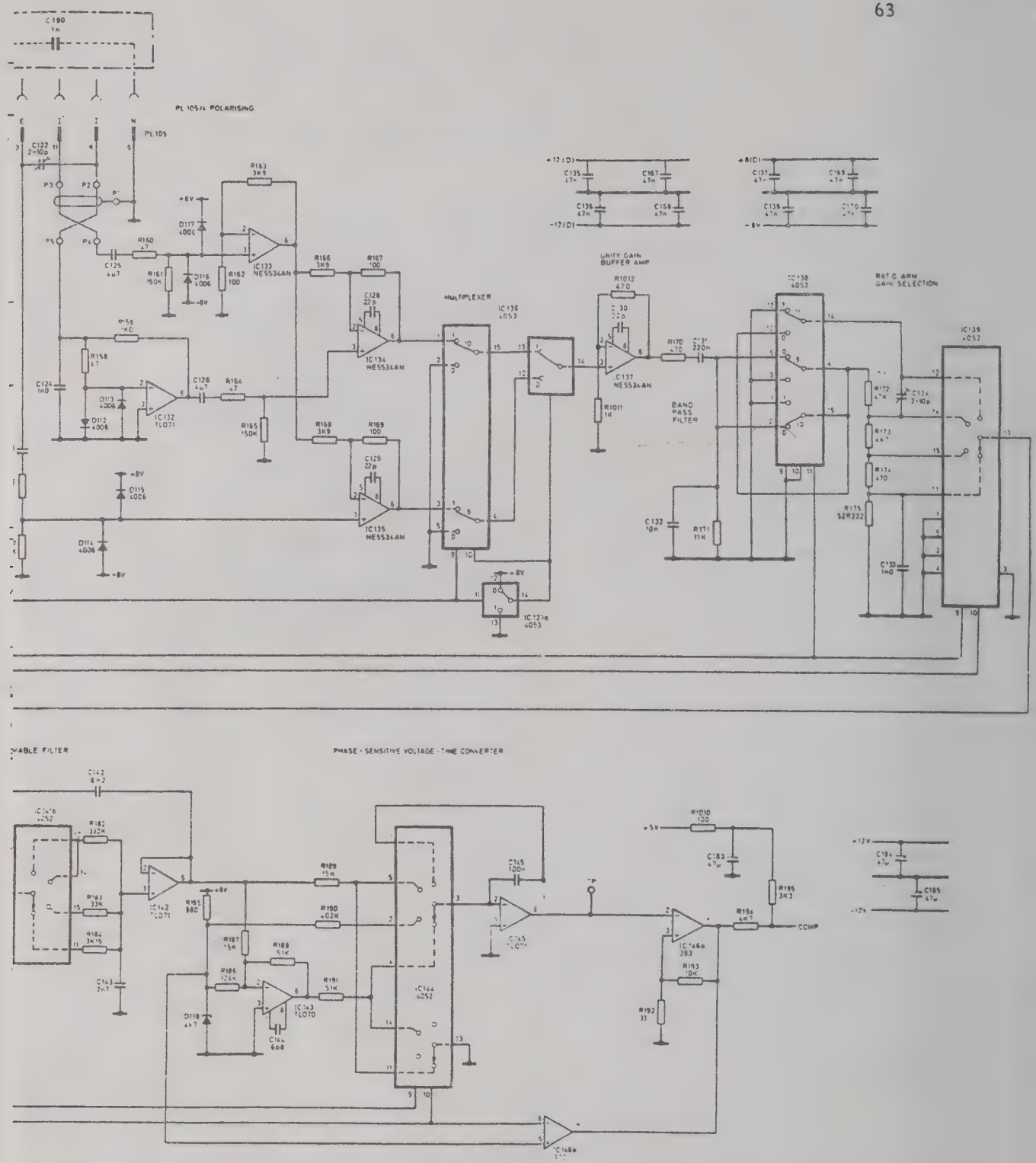


Fig. 22 Analog Circuit Diagram

APPENDIX

50/60Hz and 240/115V OPERATION

Normally, instruments are supplied for 240V, 50Hz operation, or for 115V, 60Hz operation. Keypads show the lowest test frequency as 100Hz for 50Hz models: 120Hz for 60Hz models. It is possible to convert models to the alternative voltage and/or frequency.

Voltage change-over

Power transformer T1 has split primary windings. The two sections are wired in series for 240-volt operation and in parallel for 115-volt operation. It is ESSENTIAL that the relative sense of the two sections is correct: failure to observe this will cause irreparable damage. The dots on Fig. 17 show the correct wiring.

Frequency change-over

The main pcb has provision for a link (LK1) near R5124 (annotated 'R24' on the board itself). The link (which is shown on the Digital Circuit Diagram, Fig. 21) should exist for 60Hz operation and be removed for 50Hz operation. Note that the keypad legend will need to be changed: the lowest test frequency is shown as 100Hz for 50Hz instruments while for 60Hz instruments it is 120Hz. Any labels affixed to the keypad must be flexible enough not to interfere with the touch-sensitive operation.

Safety

Voltage and/or frequency change-over must be undertaken only by qualified engineers and the instrument must be totally disconnected from the supply during the conversion. Access to the circuits is described in the section on Dismantling (page 39). It is the responsibility of the user to ensure that warning labels on the instrument are amended as necessary to meet local safety legislation, usually dependent upon National standards.

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